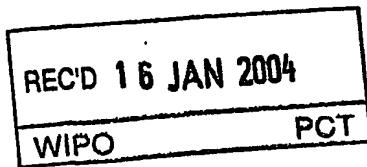




Europäisches
Patentamt

European
Patent Office

Office européen
des brevets



Bescheinigung

Certificate

Attestation

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. Patent application No. Demande de brevet n°

02027744.8

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN
COMPLIANCE WITH
RULE 17.1(a) OR (b)

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

R C van Dijk

BEST AVAILABLE COPY



Anmeldung Nr:
Application no.: 02027744.8
Demande no:

Anmeldetag:
Date of filing: 11.12.02
Date de dépôt:

Anmelder/Applicant(s)/Demandeur(s):

MERCK PATENT GmbH
Frankfurter Strasse 250
64293 Darmstadt
ALLEMAGNE

Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Liquid crystal composition for use in bistable liquid crystal devices

In Anspruch genommene Priorität(en) / Priority(ies) claimed /Priorité(s)
revendiquée(s)
Staat/Tag/Aktenzeichen/State/Date/File no./Pays/Date/Numéro de dépôt:

Internationale Patentklassifikation/International Patent Classification/
Classification internationale des brevets:

G02F/

Am Anmeldetag benannte Vertragstaaten/Contracting states designated at date of
filling/Etats contractants désignés lors du dépôt:

AT BE BG CH CY CZ DE DK EE ES FI FR GB GR IE IT LI LU MC NL PT SE SI SK

**Merck Patent Gesellschaft
mit beschränkter Haftung
64271 Darmstadt**

**Liquid crystal composition for use in bistable
liquid crystal devices**

Liquid crystal composition for use in bistable liquid crystal devices

The invention is directed to the use of a liquid crystal composition in a
5 bistable liquid crystal device and especially in a zenithal bistable nematic
liquid crystal device, a nematic liquid crystal medium, and a bistable liquid
crystal device comprising the liquid crystal composition.

Electrooptical devices utilizing liquid crystal media for displaying information
10 are well known and used in a wide variety of technical applications (see, for
a review, H. Kawamoto, Proc. IEEE, 90, 460 (2002)). Among these,
nematic liquid crystal devices are the most prominent; there are, for
instance, twisted nematic (TN) liquid crystal devices (M. Schadt and W.
15 Helfrich, Appl. Phys. Lett., 18, 127 (1971)) and super-twisted-nematic
(STN) liquid crystal devices (see, inter alia, T.J. Scheffer and J. Nehring,
Appl. Phys. Lett., 48, 1021 (1984)). These devices are monostable, i.e. the
liquid crystal medium is switched to an ON state by application of a suitable
voltage, and is allowed to switch to an OFF state when the voltage applied
falls below a lower voltage level. In order to display complex information
electrooptical devices need to comprise a number of picture elements that
20 can be switched independently of each other. However, when direct or
even multiplex addressing of pixels are used, the number of elements
addressable in nematic liquid crystal displays is limited, in the first case by
mere geometrical requirements of the electrical connections and in the
second case by the steepness of the device's transmission versus the
25 voltage curve.

This limitation can be overcome by incorporating thin film transistors (TFT)
into each picture element. Such devices, also known as active matrix (AM)
displays, enable addressing of a high number of picture elements and thus
30 of large area high resolution displays and with relatively low voltage
requirements. Some of these devices are also mechanically rather stable

and have a wide temperature range. Although this allows the construction of small and portable battery powered displays, for certain applications the techniques have several drawbacks. Manufacturing AM displays is still a complicated process involving the building up of a complex assembly which contributes to rather high costs of production. Since the device has no intrinsic or internal memory, constant update of the display even for static images is required. This causes relatively high power consumption and, hence, rather poor battery life time. This is especially undesired with portable devices displaying information that is changed only from time to time or in a limited part of the display such as mobile phones, personal digital assistants (PDAs), pagers, electronic shelf edge labels, and the like.

An approach to avoid the limitations and drawbacks of these nematic liquid crystal devices is to use displays with an internal memory effect, e.g. a bistable liquid crystal device. Bistability means that the molecules of the liquid crystal medium inside the device can adopt two different stable states. Consequently, by applying a suitable addressing scheme the liquid crystal molecules of the medium are switched into a first stable state which persists even after addressing; utilization of another addressing scheme causes the liquid crystal molecules to adopt a second stable state that likewise persists after addressing.

Ferroelectric liquid crystal displays using smectic liquid crystal materials can be made into bistable devices. They have, however, several disadvantages, e.g. lack of shock resistance, narrow operating temperature range, and low cell gap causing manufacturing difficulties. Therefore, these ferroelectric devices are unlikely to fulfill the requirements to displays for the portable devices mentioned above.

However, not only ferroelectric smectic liquid crystals are capable of being used in bistable devices but also nematic liquid crystals. Besides other approaches that utilize bistable bulk configurations adopted by nematic liquid crystals (see, for instance, I. Dozov *et al.*, "Recent improvements of 5 bistable nematic displays switched by anchoring breaking (BiNem[®])", Proceedings SID 01 (2001), 16.1, 224 and references therewithin), a promising way of achieving bistability in a nematic liquid crystal display is to use a surface alignment which can support two or more stable states. As discussed in literature (see, for instance, J.C. Jones, G. Bryan-Brown, E. 10 Wood, A. Graham, P. Brett and J. Hughes, "Novel bistable liquid crystal displays based on grating alignment", in "Liquid Crystal Materials, Devices, and Flat Panel Displays", R. Shashidhar, B. Gnade, Eds., Proceedings of SPIE Vol. 3955 (2000), 84 and references cited therein) two types, azimuthal and zenithal bistability, can be distinguished.

15

In the first instance (i.e. azimuthal bistability), the director of the liquid crystal molecules in the display having a grating alignment on the surface of one of the display cell's plates (or substrates) will lie parallel to said plate in both stable states; that means that switching between the stable states 20 occurs within the plane of the display cell's plates (see, for instance, WO 92/00546 and WO 95/22077 which describes the use of a substrate having a bigrating alignment layer). However, reproducing selection of the stable states is found to be difficult and switching generally requires a high switching voltage.

25

On the other hand, zenithal bistability is observed when the zenithal bistable surface is used (see Figure 1; the tiny lines represent the local director of the liquid crystal molecules that are oriented by interaction with the surface grating and appropriate alignment layer). With such a surface, 30 the director of the liquid crystal molecules has two possible configurations with different pretilt angles in the same azimuthal plane (i.e. the plane

perpendicular to the surface of the display cell's substrate). The first state is the high tilt state while the second state is the low tilt state. The grating of the zenithal bistable surface is defined by its amplitude a and its pitch L ; typical values are for L of about 1 μm and for a of about 0.6 to 0.8 μm (see
5 WO 97/14990 and, for more details, WO 02/08825; and J.C. Jones, G. Bryan-Brown, E. Wood, A. Graham, P. Brett and J. Hughes, "Novel bistable liquid crystal displays based on grating alignment", in "Liquid Crystal Materials, Devices, and Flat Panel Displays", R. Shashidhar, B. Gnade, eds., Proceedings of SPIE Vol. 3955 (2000), 84).

10 A homeotropic orientation can be, for example, induced by coating the grating with a homeotropic alignment layer; this orientation ensures that the director of the liquid crystal molecules does not lie parallel to the grooves of the grating. Although the orientation of the director of the liquid crystal
15 molecules is perpendicular to the (local) surface, i.e. varying with the location on the surface along a direction perpendicular to the grooves, the orientation in the "bulk" is very much influenced by the opposite surface alignment in both states. Switching from one stable state to the other may be achieved by applying a simple electrical pulse thereby causing a switch
20 from a black display or picture element to a white one (or vice versa) with the appropriate polariser configuration and retardation, and switching back to the original state occurs upon application of a pulse of opposite polarity thereby causing a switch from white to black (or vice versa). Switching may also be induced by using pulses of same polarity but with much higher
25 voltages (also referred to as "reverse switching"); however, reverse switching is a detrimental effect which limits the operation of a zenithal bistable nematic device in terms of the addressing and so a high a voltage as possible is desired for the reverse switching.

30

In general, for obtaining zenithal bistability only one of the two display cell's substrates is provided with a surface grating. The opposite plate may have a surface providing a homeotropic alignment of the liquid crystal director (VAN mode, see Figure 2a)) or a surface inducing planar alignment of the director (twisted mode, see Figure 2b)) thereby causing the twisting of the liquid crystal director around the axis perpendicular to the substrates across the cell for the low tilt state. For details with regard to cell geometry and configuration, exact cell parameters, addressing means, assembling of the entire zenithal bistable device (including use of polarisers) and so on, 5 see the disclosure of WO 97/14990, E.L. Wood, G.P. Bryan-Brown, P. Brett, A. Graham, J.C. Jones, and J.R. Hughes, "Zenithal Bistable Device (ZBDTM) Suitable for Portable Applications, SID 00 Digest (2000), 124, J.C. Jones, J.R. Hughes, A. Graham, P. Brett, G.P. Bryan-Brown, and E.L. 10 Wood, "Zenithal Bistable Devices: Towards the electronic book with a simple LCD", IDW '00 (2000), 301, and the detailed discussion given in 15 J.C. Jones, G. Bryan-Brown, E. Wood, A. Graham, P. Brett and J. Hughes, "Novel bistable liquid crystal displays based on grating alignment", in "Liquid Crystal Materials, Devices, and Flat Panel Displays", R. Shashidhar, B. Gmade, eds., Proceedings of SPIE Vol. 3955 (2000), 84, and references 20 cited therein.

Utilizing zenithal bistability in electrooptical devices offers attractive features:

- Image retention on a display without continuous update combined 25 with
- High mechanical shock stability
- Low power consumption since the display only needs addressing when the image changes
- Infinite multiplexibility for unlimited resolution without the need for 30 TFT elements
- Transmissive and reflective modes possible
- Suitability for use with plastic substrates

Besides the assembly and make up of the zenithal bistable display, another key issue to the zenithal bistable device technology is the nematic liquid crystal medium used inside the display's cell.

5

The zenithal bistable device and hence the liquid crystal medium have to meet several requirements more or less depending on the specific use of the device. Since there is no consistent theory so far that might predict the physical variables to be optimized, it turned out to be helpful using a set of (semi-)empirical parameters for evaluating liquid crystal media with respect to their usefulness in zenithal bistable nematic devices. These are illustrated in the so-called τ -V curve for switching voltages of pulse duration τ and for 10 and 90% switching levels with opposite polarities (see figure 3) for a liquid crystal mixture of the prior art, namely MLC-6204-000 of Merck KGaA, Darmstadt, Germany.

15

Firstly, in order to minimize power consumption, to allow more flexibility with the addressing of the device's picture elements and to remain within the limits of standard STN drivers a low switching field and correspondingly a low operating voltage is desirable for switching from one bistable state to the other. For material comparison one can determine the switching field E for a pulse (usually a 100 μ s pulse duration) from the switching voltage V that gives a transmission change from, e.g., 0 to 90% transmission (black-to-white; B-W) for a particular liquid crystal mixture in a given test cell providing zenithal bistability. (In general, one can also use the 100 to 10% transmission change transition of white-to-black, W-B, where the switching field of which may be higher or lower than the B-W transition depending on the grating's shape and dimensions.) In order to take into account the voltage drop across the grating (which varies for different types of gratings as well as cell thickness) the value of E actually measured is corrected to distinguish the field just across the liquid crystal again for comparison

purposes giving the corrected switching field $E_{LC@100\mu s}$ for a 100 μs pulse. Here, an additional factor of 1.5 μm is added to the cell thickness d when calculating the field just across the liquid crystal:

5 $E_{100\mu s} = V_{100\mu s}/d$ and $E_{LC@100\mu s} = V_{100\mu s}/(d+1.5)$ where d is in μm .

Multiplying $E_{LC@100\mu s}$ with optimum cell gap d_{opt} (that can be approximated by using the TN 1st minimum condition $d_{opt} = \lambda\sqrt{3}/(2\Delta n)$ with $\lambda = 555$ nm and Δn being the optical anisotropy of the liquid crystal medium) gives the operating voltage V_{opt} corresponding to the optimum cell gap for a 100 μs pulse for just the liquid crystal. $E_{LC@100\mu s}$ and so V_{opt} depend on the liquid crystal medium used. The optimum cell gap is considered only for the twisted mode (see Figure 2b)) here but comparisons can also be made for the VAN mode (see Figure 2a)), where the retardation of the hybrid state will be matched to either a half-wave plate or quarter-wave plate depending on the polariser configuration ($d\Delta n = \lambda/2$ and $d\Delta n = \lambda/4$ respectively).

The second empirical parameter that needs to be taken into account is the operating window ΔV_{opt} corresponding to the optimum cell gap. It describes the effect of reverse switching: When applying a pulse with a given time slot of, e.g. 400 μs , and a defined pulse polarity, e.g. B-W, one observes the desired switching at a specific value of the switching field and a further reverse switching (e.g. W-B in this case) which is not induced by a pulse of inverse polarity but by a pulse of the same polarity at an increased switching field. For technical purposes, obviously said operating window ought to be as wide as possible to permit more flexibility of the driving schemes used and particularly in relation to achieving good grayscale operation (see J. C. Jones, S. M. Beldon and E. L. Wood, "Greyscale in Zenithal Bistable LCD: The Route to Ultra-low Power Colour Displays", seminar talk on the ASID meeting 2002 of the Society for Information Display.) It can be represented by $\Delta E_{LC@400\mu s}$, that is the corrected

difference between the 90% reverse switching field and the 90% B-W switching field for a 400 μ s pulse:

$$\Delta E_{400\mu s} = \Delta V_{400\mu s}/d \text{ and } \Delta E_{LC@400\mu s} = \Delta V_{400\mu s}/(d+1.5) \text{ where } d \text{ is in } \mu\text{m.}$$

5

Taking into account the optimum cell gap d_{opt} by multiplying with $\Delta E_{LC@400\mu s}$ eventually gives the operating window ΔV_{opt} ($d_{opt}\Delta E_{LC@400\mu s} = \Delta V_{opt}$).

10

A further parameter, the *optical response time* τ_{opt} corresponding to the optimum cell gap, describes how fast the liquid crystal medium changes between stable states upon application of an electric pulse. It can be determined by measuring the response time τ for the 10-90% B-W transition using a 100 μ s pulse in the actual test cell; then, in order to normalize the experimental values, τ is multiplied by $(d_{opt}/d)^2$ giving τ_{opt} (with d_{opt} being the optimum cell gap as calculated above for V_{opt} and d being the actual cell gap of the test cell used). The W-B transition is much faster (less than 1ms) and so indeed the B-W response time is of most importance when assessing the properties of the liquid crystal medium used. The smaller τ_{opt} the faster the optical response of the liquid crystal medium. A small τ_{opt} (of about 40 ms or less) may be desirable for certain electrooptical applications, e.g. displaying moving pictures. It is even more preferred for specific video applications that τ_{opt} is less than about 16ms so as not to observe flash.

20

25

Still another parameter of great importance is the *clearing point* T_N of the liquid crystal medium describing the temperature at which the nematic mixture becomes isotropic. For many technical purposes and for increasing the variability of electrooptical devices utilizing zenithal bistability (and so the possible applications), liquid crystal media having a high clearing point, preferably of at least 80 °C or more, are desired.

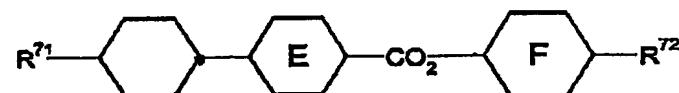
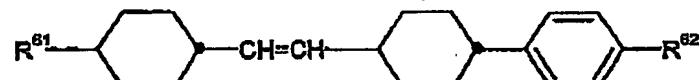
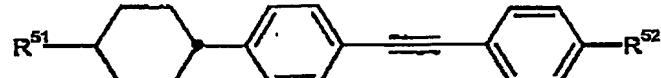
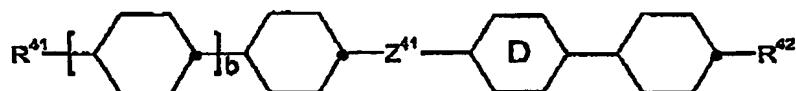
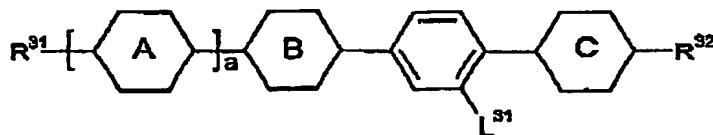
Those liquid crystal media the use of which in zenithal bistable devices have been described in the prior art do not meet all the parameter requirements outlined above. Even liquid crystal mixture MLC-6204-000 (available from Merck KGaA, Darmstadt, Germany) that has been used in zenithal bistable devices as the preferred medium (WO 01/40853, Example 6; J.C. Jones, G. Bryan-Brown, E. Wood, A. Graham, P. Brett and J. Hughes, "Novel bistable liquid crystal displays based on grating alignment", in "Liquid Crystal Materials, Devices, and Flat Panel Displays", R. Shashidhar, B. Gnade, Eds., Proceedings of SPIE Vol. 3955 (2000), 84) has a clearing point T_{NI} of only 62.4 °C that is rather low for use in zenithal bistable device for many possible applications.

15 The present invention therefore encounters the problem to provide a liquid crystal composition that is suitable for use in a bistable liquid crystal device and especially in a zenithal bistable nematic device and has improved properties.

20 The problem is solved by the use of a liquid crystal composition in a bistable liquid crystal device, said device being preferably a zenithal nematic liquid crystal device, whereby said composition comprises

- 25 ▪ at least 30 weight% (based on the total weight of the composition) of a component (α) containing one or more compounds having a dielectric anisotropy $\Delta\epsilon$ of at least 25, whereby at least 25 weight% (based on the total weight of the composition) of said compounds have a dielectric anisotropy $\Delta\epsilon$ of at least 40; and
- 30 ▪ at least 5 weight% (based on the total weight of the composition) of a component (β); whereby said component (β) comprises at least one compound of formula III and/or at least one compound of formula IV and/or at least one compound of formula V and/or at least one compound of formula VI and/or at least one compound of formula VII

- 10 -



in which

a and b are independently of each other 0 or 1;

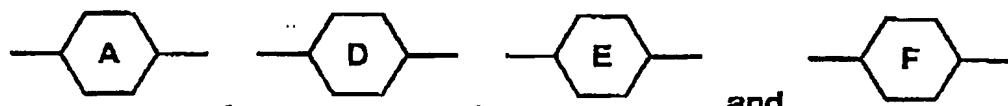
R³¹, R³², R⁴¹, R⁴², R⁵¹, R⁵², R⁶¹, R⁶², R⁷¹ and R⁷² are independently of each other C₁-C₁₆ alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH₂ groups may be replaced independently of each other by -O-, -S-, -CH=CH-, -C≡C-, -CO-O-, -OC-O- such that there are no hetero atoms adjacent to each other;

L³¹ is H or F;

Z⁴¹ is -CO-O-, -CH₂O-, -CF₂O-, -CH₂CH₂-, -CF₂CF₂-, -CH₂CF₂-, -CF₂CH₂-, -CH=CH- or -C≡C-;

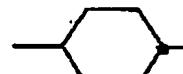
30

- 11 -



5

are independently of each other



or



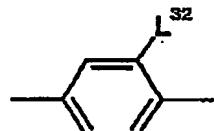
10



is



or



15

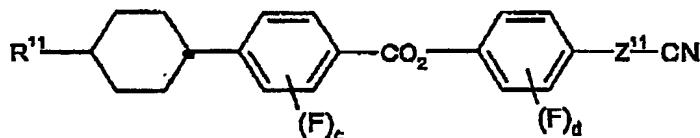
in which

L³² and L³³

are independently of each other H or F.

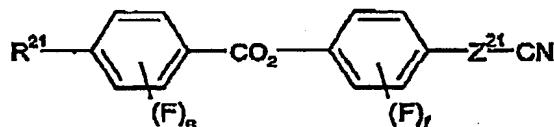
It is preferred that said component (a) comprises at least one compound of formula I and/or at least one compound of formula II

20



I

25



II

c, d, e and f are independently of each other 0, 1, 2, 3 or 4;

R¹¹ is C₁-C₁₅ alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH₂ groups may be replaced independently of each other by -O-, -S-, -CH=CH-, -C≡C-, -CO-O-, -OC-O- such that there are no hetero atoms adjacent to each other;

R²¹ is C₂-C₁₅ alkenyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH₂ groups may be replaced independently of each other by -O-, -S-, -CH=CH-, -C≡C-, -CO-O-, -OC-O- such that there are no hetero atoms adjacent to each other;

5

Z¹¹ and **Z²¹** are independently of each other a single bond or -C=C-.

A further subject matter of this invention is a bistable liquid crystal device comprising

10

- two outer substrates which, together with a frame, form a cell;
- a liquid crystal composition present in said cell;
- electrode structures with alignment layers on the inside of said outer substrates whereby at least one alignment layer comprises an alignment grating that permits the molecules (compounds) of the liquid crystal composition to adopt at least two different stable states whereby the assembly of said electrode structures with said alignment layers being such that a switching between the said at least two different stable states is achieved by applying suitable electric signals to said electrode structures;

15

- whereby said liquid crystal composition is said liquid crystal composition as described above and below and that comprises said components (α) and (β).

25

In particular, said bistable liquid crystal device is a zenithal bistable nematic liquid crystal device in which said electrode structures with alignment layers on the inside of said outer substrates have at least one alignment layer that comprises an alignment grating that permits the compounds (or the director of the molecules) of said liquid crystal composition to adopt at least two different stable states with different pretilt angles in the same azimuthal plane whereby the assembly of said electrode structures with said alignment layers being such that a switching between the said at least two

30

different stable states is achieved by applying suitable electric signals to said electrode structures.

It will be acknowledged that the invention is described hereinafter primarily
5 with regard to the use of the liquid crystal composition above in a zenithal
bistable nematic liquid crystal device although it may be used in other liquid
crystal devices as well, for instance, in bistable liquid crystal devices like
azimuthal bistable liquid crystal devices as disclosed, inter alia, in WO
92/00546 and WO 95/22077. Thus, details are given for the zenithal
10 bistable nematic liquid crystal device but can easily be adapted to the
requirements of other types of bistable liquid crystal devices.

The zenithal-bistable-nematic-device-and-the-liquid-crystal-composition-for
use in a zenithal bistable nematic device according to the invention show
15 an improved set of parameters said parameters being, inter alia, operating
voltage, operating window, optical response time and, especially, clearing
point. It should be noticed that, for instance, the clearing point of the liquid
crystal compositions for use in the zenithal bistable nematic devices of the
invention is significantly higher than the clearing point of liquid crystal
20 mixtures previously used in zenithal bistable nematic devices. Operating
voltage and operating window are both in a range useful for operating of a
zenithal bistable nematic device.

The cell that is part of the zenithal bistable nematic device according to the
25 invention may be any conventional cell which allows the nematic liquid
crystal composition to adopt at least two different zenithal bistable states.
Two possible stable states are schematically depicted in Figure 1. The two
different zenithal bistable states are characterized by two different pretilt
angles that are adopted by the liquid crystal molecules in the same
30 azimuthal plane. The cell comprises a frame and two outer substrates or
plates and has electrode structures with alignment layers on the inside of
said substrates. At least one of these alignment layers has an zenithal

alignment grating known to those skilled in the art and as described, for instance, in WO 97/14990, WO 01/40853, WO 02/08825, and J.C. Jones, et al., Proceedings of SPIE Vol. 3955 (2000), 84.

5 The electrode structures are assembled with the alignment layer(s) in such a way that (in the case of two stable states) switching from one stable state to the other can be achieved by applying suitable electric signals to the electrode structures thereby applying said electric signals to the liquid crystal composition inside the cell. Commonly, single pulses can be used

10 as such suitable electric signals. Details are known to the artisan and described in WO 97/14990, WO 01/40853, WO 02/08825, J.C. Jones, J.R. Hughes, A. Graham, P. Brett, G.P. Bryan-Brown, IDW '00 (2000), 301, J.C. Jones, et al., Proceedings of SPIE Vol. 3955 (2000), 84, and E. L. Wood, P. J. Brett, G. P. Bryan-Brown, A. Graham, R. M. Amos, S. Beldon, E.

15 Cubero and J. C. Jones, "Large Area, High Resolution Portable ZBD Display", SID 02 Digest (2002), 22-25.

The substrate opposite to the substrate having the grating alignment layer may have an homeotropic alignment due to suitable surface treatment (see 20 Figure 2a)). Switching upon application of an electric pulse occurs from the high tilt or vertically aligned state to the low tilt or hybrid aligned state. This switch gives a black-to-white (B-W) change if the cell is placed between crossed polarizers (at 45° to the grating direction), with the brightest white state obtained when the vertically aligned state acts as a half-waveplate 25 (dΔn=λ/2). This switching mode is called *VAN mode*. Zenithal bistable devices utilizing the *VAN mode* are very insensitive to cell gap variations. They require additional optical compensators to achieve wide viewing angles. A second switching mode of zenithal bistable devices is called *TN mode* (see Figure 2b)): The substrate opposite to the substrate having the 30 grating alignment layer has a alignment layer, usually of rubbed polyimide, causing planar alignment of the liquid crystal molecules on said substrate.

This in turn causes the twisting of the liquid crystal director around their axis perpendicular to the substrates across the cell. Switching upon application of an electric pulse now occurs from the low tilt or twisted aligned state to the high tilt or hybrid aligned state. This switch gives a 5 black-to-white (B-W) change if the cell is placed between parallel polarizers and using the slightly modified TN 1st minimum condition (as given above) accounting for the influence of the ordinary refractive index of the hybrid state. Due to a high normal incidence contrast ratio additional optical compensators for achieving wide viewing angles are not required in a 10 transmissive display. Therefore the TN mode is preferred for most of the technical applications of zenithal bistable nematic devices. It is also possible to build up a zenithal bistable reflective display. For details, also with regard to the polarizers used, it is referred to WO 97/14990, E.L.

Wood, G.P. Bryan-Brown, P. Brett, A. Graham, J.C. Jones, and J.R. 15 Hughes, SID 00 (2000), 124, and E. L. Wood, P. J. Brett, G. P. Bryan-Brown, A. Graham, R. M. Amos, S. Beldon, E. Cubero and J. C. Jones, "Large Area, High Resolution Portable ZBD Display" SID 02 Digest (2002), 22-25.

20 In the context of the present invention and with respect to the compounds contained in the liquid crystal composition for use in bistable liquid crystal devices and especially in zenithal bistable nematic devices of the invention the term "alkyl" means - as long as it is not defined in a different manner elsewhere in this description or the claims - straight-chain and branched 25 saturated hydrocarbon (aliphatic) radicals with 1 to 15 carbon atoms; the hydrocarbon radicals may be unsubstituted or substituted with one or more substituents being independently selected from the group consisting of F, Cl, Br, I or CN. This subclass of "alkyl" containing aliphatic saturated radicals may also be designated as "alkanyl". Furthermore, "alkyl" is also 30 meant to comprise unsubstituted or likewise substituted hydrocarbon radicals in which one or more of the CH₂ groups are such replaced by -O-

("alkoxy", "oxaalkyl"), -S- ("thioalkyl"), -CH=CH- ("alkenyl"), -C≡C-
 ("alkinyl"), -CO-O- or -O-CO- that there are no adjacent hetero atoms (O,
 S). Preferably, alkyl is a straight-chain or branched saturated hydrocarbon
 having 1, 2, 3, 4, 5, 6, 7 or 8 carbon atoms and being unsubstituted or
 5 mono- or poly-substituted with F. More preferably, alkyl is meant to be
 methyl, ethyl, n-propyl, i-propyl, n-butyl, i-butyl, t-butyl, n-pentyl, neopentyl,
 n-hexyl, n-heptyl, n-octyl; CF₃, CHF₂, CH₂F; CF₂CF₃. Most preferably, alkyl
 is a straight-chain hydrocarbon of up to 8 carbon atoms.

10 Since one or more CH₂ groups of an alkyl radical may be replaced by -O-
 as described above, the term "alkyl" also comprises "alkoxy" and "oxaalkyl"
 moieties. "Alkoxy" means "O-alkyl" in which the oxygen atom is directly
 linked to the group or ring being substituted with alkoxy and alkyl is defined
 as above. In particular, "alkyl" in "O-alkyl" means methyl, ethyl, n-propyl, i-
 15 propyl, n-butyl, i-butyl, t-butyl, n-pentyl, neopentyl, n-hexyl, n-heptyl or n-
 octyl, whereby alkyl is optionally substituted with F. Most preferably, alkoxy
 is -OCH₃, -OC₂H₅, -O-n-C₃H₇, -O-n-C₄H₉, -O-t-C₄H₉, -OCF₃, -OCHF₂,
 -OCHF or -OCHFCHF₂. In the context of the present invention the term
 "oxaalkyl" comprises alkyl moieties in which at least one non-terminal CH₂-
 20 group is replaced by O in such a way that there are no adjacent oxygen
 atoms. Preferably, oxaalkyl comprises straight-chain radicals of the formula
 C_tH_{2t+1}-O-(CH₂)_u- in which t and u are independently of each other 1, 2, 3,
 4, 5 or 6; especially t is 1 or 2 and u is an integer from 1 to 6.

25 If one or more of the CH₂ groups of alkyl are replaced by sulfur a "thioalkyl"
 radical is obtained. Thioalkyl comprises alkyl moieties in which at least one
 terminal or non-terminal CH₂ group is replaced by S (sulfur) in such a way
 that there are no adjacent sulfur atoms. Preferably, thioalkyl comprises
 straight-chain radicals of the formula C_tH_{2t+1}-S-(CH₂)_u- in which t is 1, 2, 3,
 30 4, 5 or 6 and u is 0, 1, 2, 3, 4, 5 or 6; especially t is 1 or 2 and u is zero or
 an integer from 1 to 6.

In the context of the present invention the term "alkenyl" means an alkyl radical in which one or more $-\text{CH}=\text{CH}-$ moieties are present. When two $-\text{CH}=\text{CH}-$ moieties are present the radical may also be designated as "alkadienyl". An alkenyl radical may comprise 2 to 15 carbon atoms and 5 may be straight-chain or branched. It can be unsubstituted or mono- or polysubstituted with F, Cl, Br, I or CN; one or more of its CH_2 groups may be replaced independently of each other by $-\text{O}-$, $-\text{S}-$, $-\text{C}\equiv\text{C}-$, $-\text{CO-O}-$, $-\text{OC-O-}$ such that there are no hetero atoms adjacent to each other. If the 10 alkenyl $\text{CH}=\text{CH}$ moiety is not a terminal $\text{CH}_2=\text{CH}$ group it may exist in two configurations, namely the E-isomer and the Z-isomer. In general, the E-isomer (trans) is preferred. Preferably, alkenyl contains 2, 3, 4, 5, 6 or 7 carbon atoms and means vinyl, 1E-propenyl, 1E-but enyl, 1E-pentenyl, 1E-hexenyl, 1E-heptenyl, 2-propenyl, 2E-but enyl, 2E-pentenyl, 2E-hexenyl, 15 2E-heptenyl, 3-but enyl, 3E-pentenyl, 3E-hexenyl, 3E-heptenyl, 4-pentenyl, 4Z-hexenyl, 4E-hexenyl, 4Z-heptenyl, 5-hexenyl and 6-heptenyl. More preferred alkenyl is vinyl, 1E-propenyl, 3E-but enyl.

In the case one or more CH_2 alkyl groups are replaced by $-\text{C}\equiv\text{C}-$ an alkinyl radical is obtained. Also the replacement of one or more CH_2 -alkyl groups by $-\text{CO-O-}$ or $-\text{O-CO-}$ is possible. The following of these radicals are 20 preferred: acetoxy, propionyloxy, butyryloxy, pentanoyloxy, hexanoyloxy, acetyloxymethyl, propionyloxymethyl, butyryloxymethyl, pentanoyloxymethyl, 2-acetoxyethyl, 2-propionyloxyethyl, 2-butyryloxyethyl, 2-acetoxypropyl, 3-propionyloxypropyl, 4-acetoxybutyl, 25 methoxycarbonyl, ethoxycarbonyl, propoxycarbonyl, butoxycarbonyl, pentoxy carbonyl, methoxycarbonylmethyl, ethoxycarbonylmethyl, propoxycarbonylmethyl, butoxycarbonylmethyl, 2-(methoxycarbonyl)ethyl, 2-(ethoxycarbonyl)ethyl, 2-(propoxycarbonyl)-ethyl, 3-(methoxycarbonyl)-propyl, 3-(ethoxy-carbonyl)-propyl oder 4-(methoxycarbonyl)-butyl.

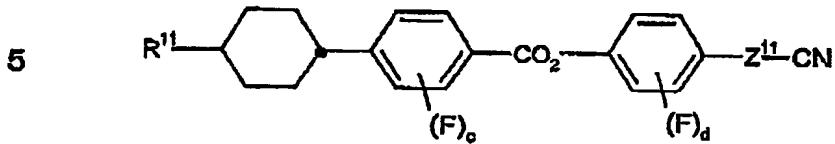
30

The liquid crystal composition for use in the (zenithal) bistable (nematic) liquid crystal device of the invention contains at least two different components, component (α) and component (β).

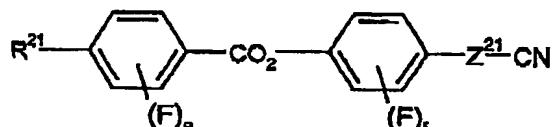
5 Component (α) contains one or preferably more compounds having a high dielectric anisotropy $\Delta\epsilon$ of 25 or more, especially of 30 or more. At least 25 weight%, preferably 30 weight% or more, (based on the total weight of the composition) of the compounds of component (α) exhibit a dielectric anisotropy $\Delta\epsilon$ of 40 or more. At least 30 weight% (based on the whole 10 composition) of component (α) need to be comprised by the liquid crystal composition of the zenithal bistable nematic device according to the invention. It is preferred that the liquid crystal composition comprises 35 weight% or more, even more preferred at least 40 weight%, still more preferred at least 45 weight%, most preferred 50 weight% or more, of said 15 component (α).

It has been found by the inventors that component (α) preferably comprises either one or more compounds of formula I or one or more compounds of formula II or one or more compounds of both formula I and formula II 20 (besides other compounds having the required high dielectric anisotropy that may be present). In one preferred embodiment of the invention component (α) contains at least one compound of formula I but no compound of formula II; in another preferred embodiment component (α) contains at least one compound of formula II but no compound of formula I. 25 If component (α) contains at least one compound of formula I, said compound(s) of formula I may be present in a total amount of at least 5 weight%, preferably at least 10 weight%, more preferred at least 15 weight% or more. If component (α) contains one compound of formula II, said compound of formula II may be present in an amount of about 5 to 30 weight%, preferably 8 to 25 weight%, more preferred 10 to 20 weight%. 30 However, if component (α) contains more than one compound of formula II, the total amount of these compounds is in the range of about 5 to about 55

weight%, preferably about 8 to about 35 weight%, more preferred about 9 to about 25 weight%.



10



15

With regard to compounds of formula I c and d may be independently of each other 0, 1, 2, 3 or 4, preferably 0, 1 or 2; that means that preferably each of the phenyl rings of formula I may be unsubstituted or mono- or di-substituted with fluorine. If present the F substituent(s) may be in any position of the phenyl ring substituted. Furthermore, Z^{11} can be either a single bond (so that the CN group is directly linked to the phenyl ring) or a C-C triple bond thereby forming a

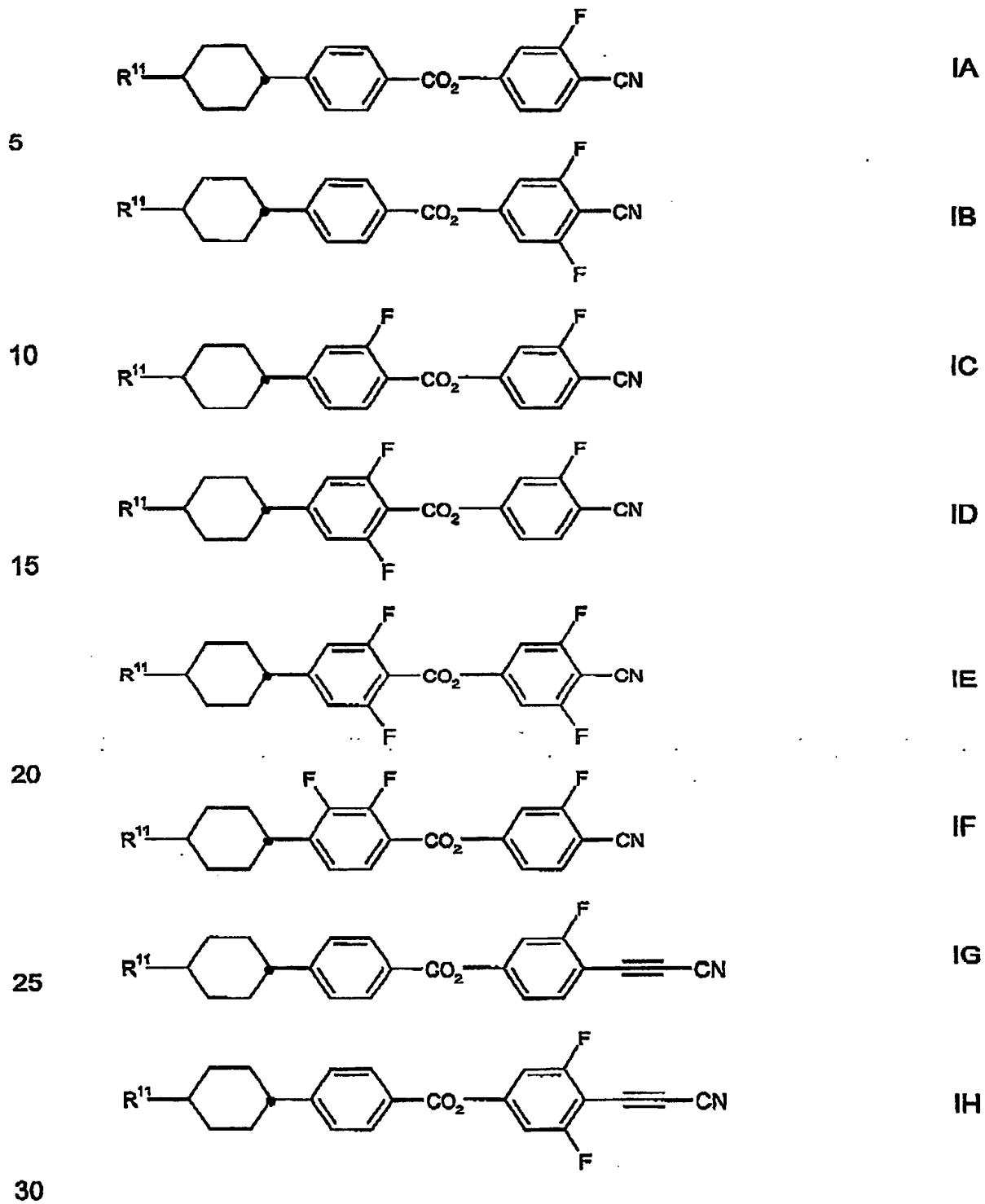
-C≡C-CN substituent of the phenyl ring. It is preferred that Z^{11} is a single bond.

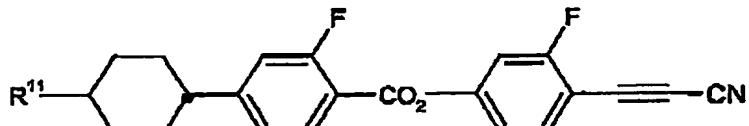
20

Preferred compounds of formula I are the following compounds:

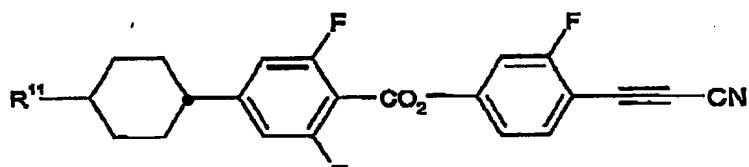
25

30

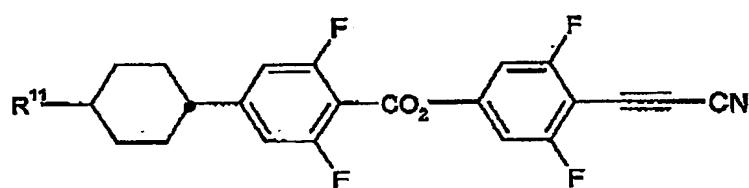




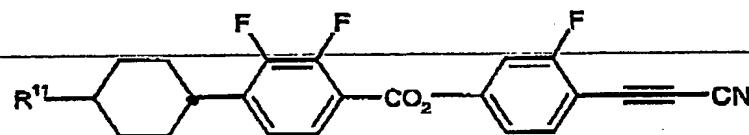
IJ



IK

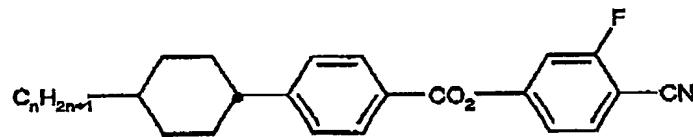


IL



IM

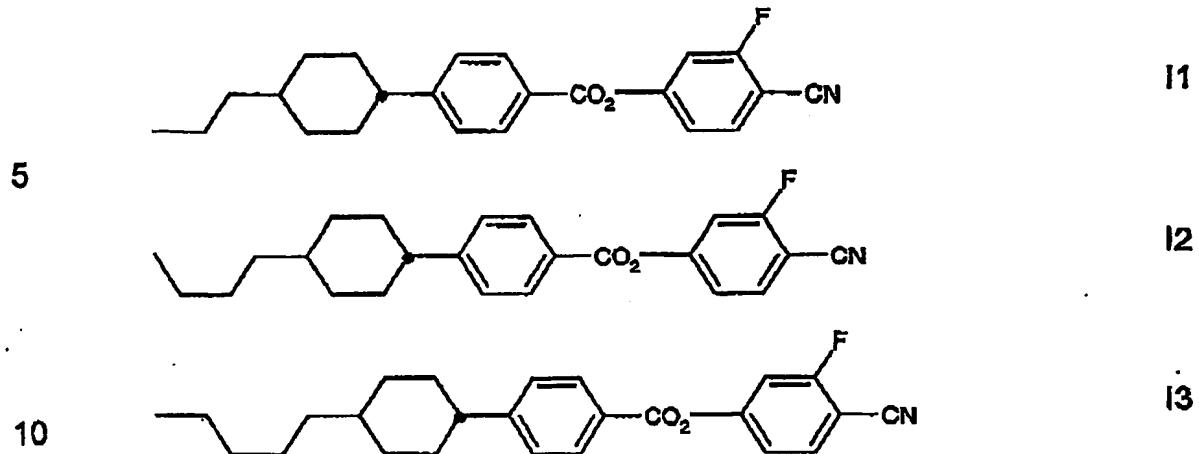
with R^{11} being defined as above. Preferably, R^{11} in formulas I and IA to IM is a straight-chain alkyl radical, especially an alkanyl radical with 1, 2, 3, 4, 5 or 6 carbon atoms. Highly preferred compounds are of general formula IA1 with $n = 1, 2, 3, 4, 5$ or 6.



IA1

Especially preferred examples of compounds of formula I being present in component (a) either alone or in combination with each other are the following compounds of formula I1 to I3:

30



It is preferred to have a mixture of all three compounds I1, I2 and I3 in the liquid crystal composition. For instance, compound I1 exhibits a dielectric anisotropy $\Delta\epsilon$ of 37.5 whereas compound I3 has a $\Delta\epsilon$ of 36.0.

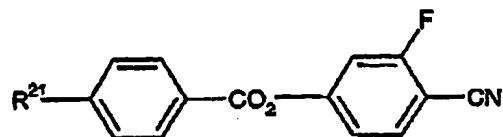
15

With regard to compounds of formula II e and f may be independently of each other 0, 1, 2, 3 or 4, preferably 0, 1 or 2; that means that preferably each of the phenyl rings of formula II may be unsubstituted or mono- or di-substituted with fluorine. If present the F substituent(s) may be in any position of the phenyl ring substituted. Furthermore, Z^{21} can be either a single bond (so that the CN group is directly linked to the phenyl ring) or a C-C triple bond thereby forming a $-C\equiv C-CN$ substituent of the phenyl ring. It is preferred that Z^{21} is a single bond.

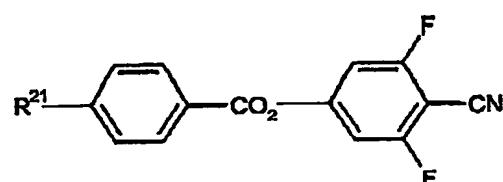
20

Preferred compounds of formula II are the following compounds:

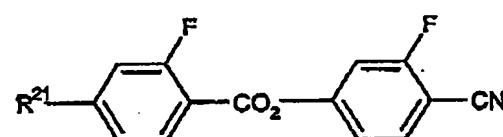
30



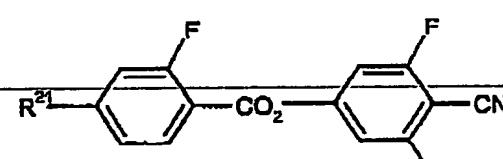
IIA



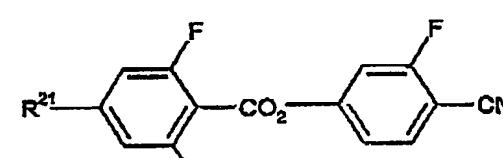
IIB



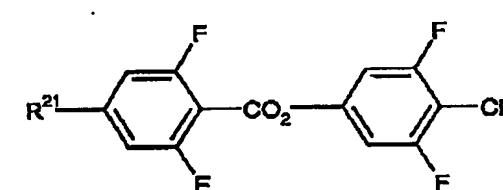
IIC



IID



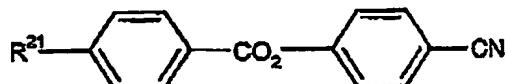
IIE



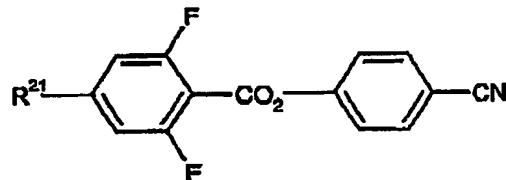
IIF

IIG

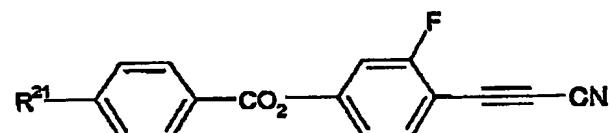
IIH



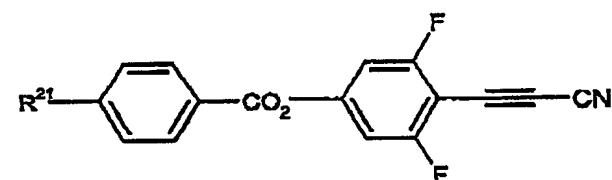
IIJ



IIK



III

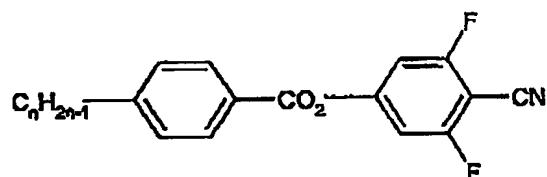


IIM

15

with R²¹ being defined as above. Preferably, R²¹ in formulas II and IIA to IIM is a straight-chain alkenyl radical, especially with 2, 3, 4, 5 or 6 carbon atoms and most preferred with a terminal C=C double bond. Highly preferred compounds are of general formula IIB1 with n = 2, 3, 4, 5 or 6.

20

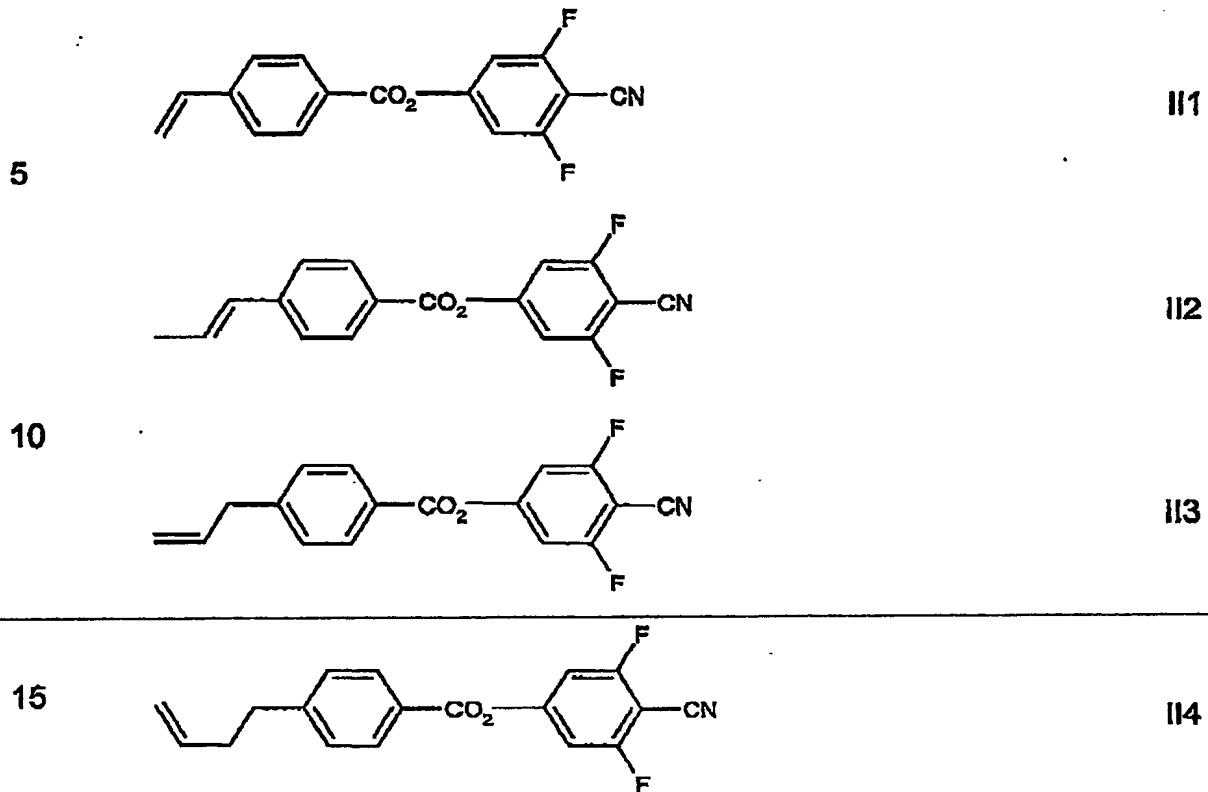


IIB1

25

Especially preferred examples of compounds of formula II being present in component (a) either alone or in combination with each other are the following compounds of formula II1 to II4:

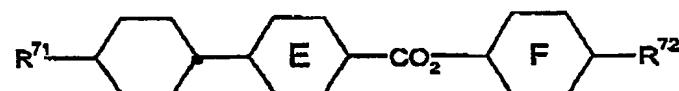
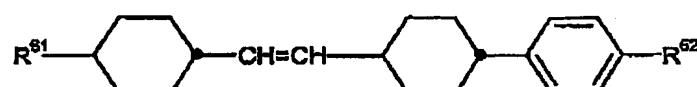
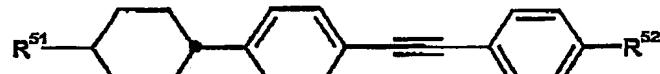
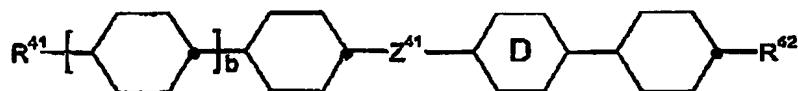
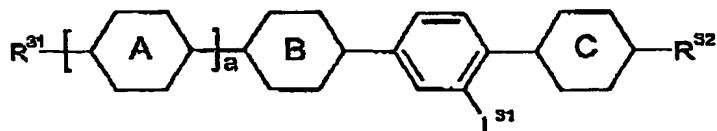
30



20 The most preferred compound of formula II is compound II4 which exhibits
a dielectric anisotropy $\Delta\epsilon$ of 59.5.

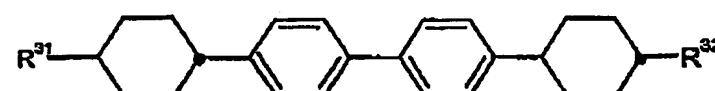
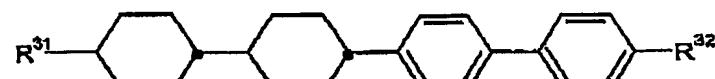
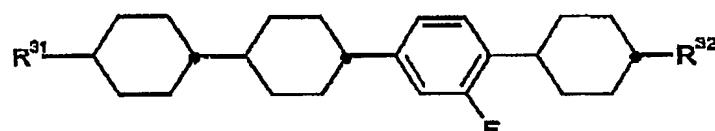
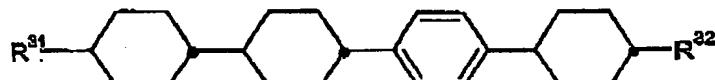
25 With respect to component (β) said component is present in the liquid
crystal composition in the zenithal bistable nematic device of the invention
in an amount of at least 5 weight% or more. Apparently, component (β) is
required for a high clearing point of the liquid crystal mixtures used in
zenithal bistable nematic devices. Component (β) comprises compounds of
formula III and/or formula IV and/or formula V and/or formula VI and/or
formula VII.

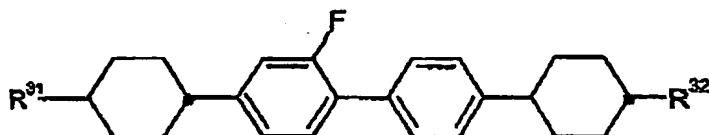
30



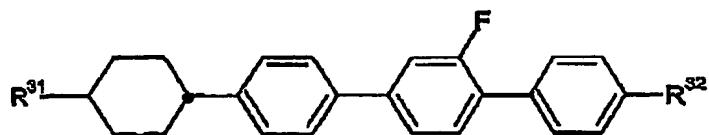
15 with a, b, R³¹, R³², R⁴¹, R⁴², R⁵¹, R⁵², R⁶¹, R⁶², R⁷¹, R⁷², L³¹, Z⁴¹ and the rings indicated by A, B, C, D, E and F being defined as above.

20 With respect to formula III it is preferred that a is 1. Preferred compounds of formula III are of the following formulas:

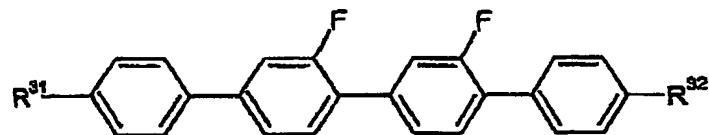




IIIE



IIIF

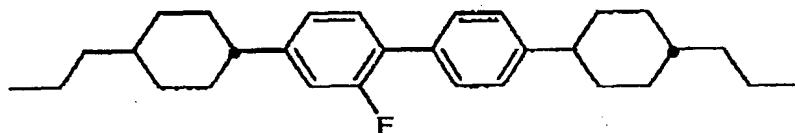


IIIG

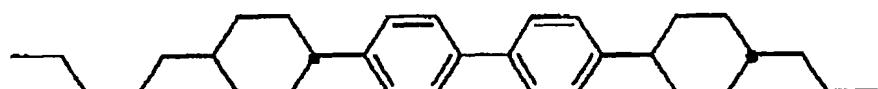
with R³¹ and R³² being as defined above. Preferably, in formulas III and IIIA to IIIG R³¹ and R³² are both independently of each other straight-chain alkyl, more preferred straight-chain alkanyl or alkenyl having 2, 3, 4, 5 or 6 carbon atoms, especially straight-chain alkanyl with 2 to 6 carbon atoms, a is 1 and L³¹ is H or F (for formula III). Highly preferred compounds are of formula IIID and IIIE. Especially preferred examples of formula III are compounds of formula III1 to III6:



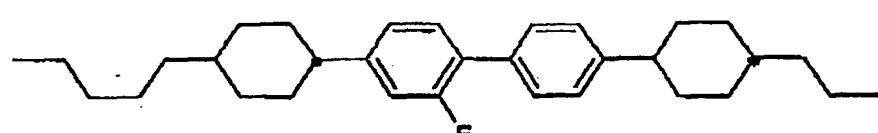
III1



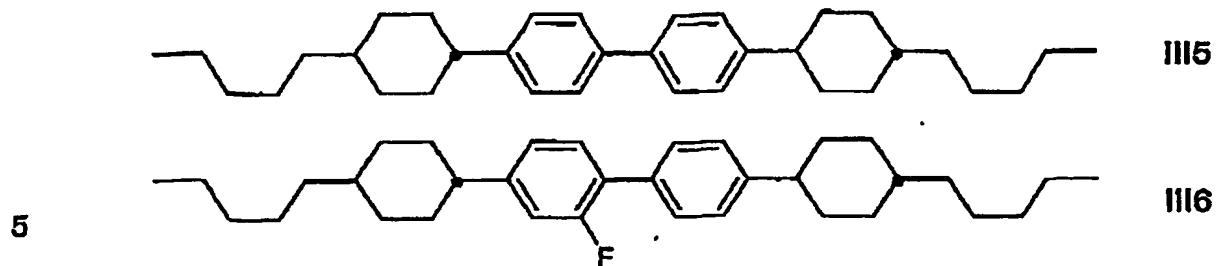
III2



III3

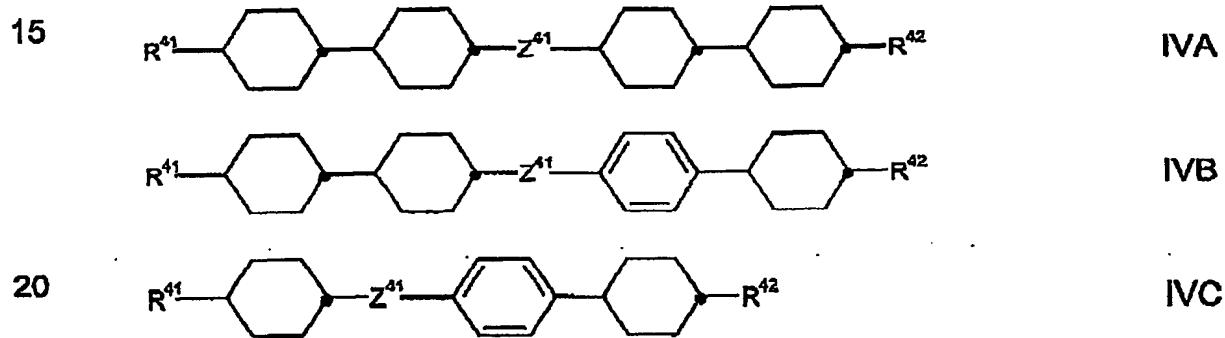


III4



10 Most preferred compounds of formula III are compounds III2, III4 and III6, and it is especially preferred to have a mixture of all three compounds in the liquid crystal composition.

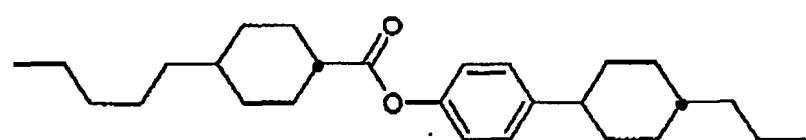
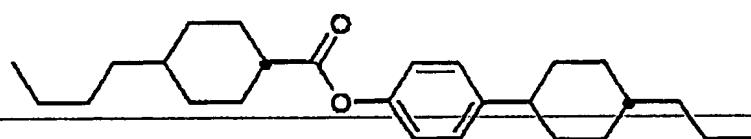
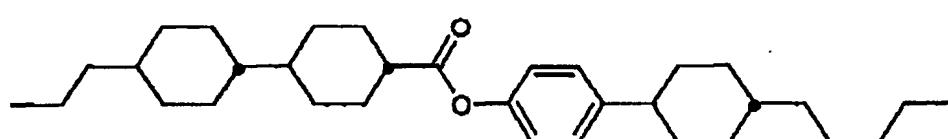
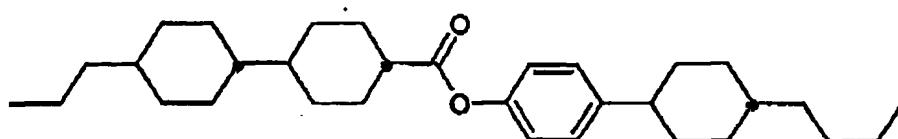
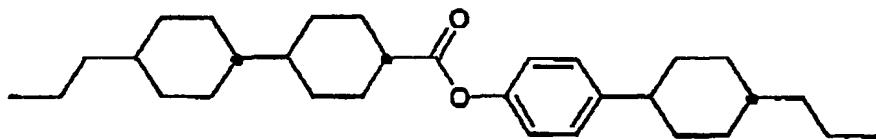
With respect to formula IV preferred compounds are of formulas IVA and IVB in which b is 1 as well as of formula IVC in which b is zero:



20 with R⁴¹, R⁴² and Z⁴¹ being as defined above; Z⁴¹ is preferably -CO-O-. R⁴¹ and R⁴² are both independently of each other straight-chain alkyl, more preferred straight-chain alkanyl or alkenyl having 2, 3, 4, 5 or 6 carbon atoms, especially straight-chain alkanyl with 2 to 6 carbon atoms.

25 Compounds of formula IVB are more preferred. Especially preferred examples of formula IV are compounds of formulas IV1 to IV3 as well as of formulas IV4 and IV5:

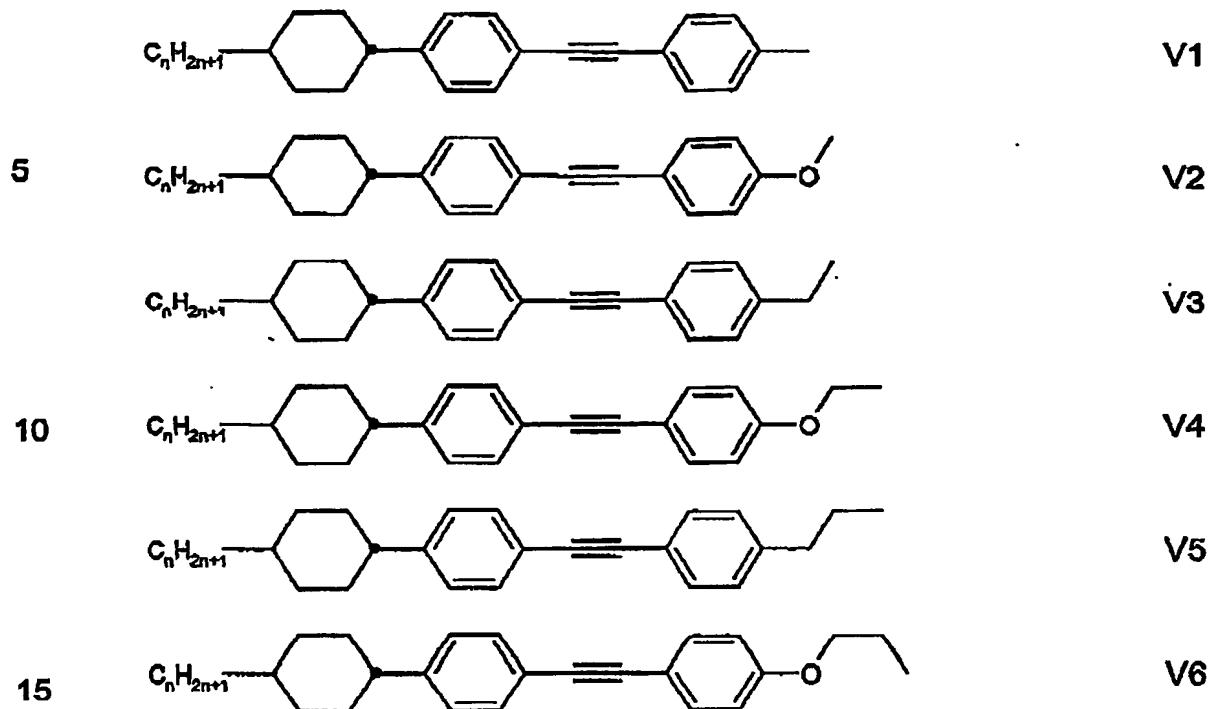
30



It is especially preferred to have a mixture of compounds IV1, IV2 and IV3
20 in the liquid crystal composition.

Preferably, in formula V R⁵¹ is straight-chain alkyl, more preferred straight-chain alkanyl or alkenyl having 2, 3, 4, 5 or 6 carbon atoms, especially straight-chain alkanyl with 2 to 6 carbon atoms, and R⁵² is straight-chain alkyl or, more preferred, alkoxy having 1, 2, 3 or 4 carbon atoms. Especially preferred examples of formula V are compounds of formula V1 to V6:
25

30



in which n is an integer from 1 to 6, preferably 2, 3 or 4, especially 3.

Preferred compounds of formula V are compounds of formula V2, V4 and

V6 with n = 3 (giving an n-propyl substituent). It is preferred to have a

20 mixture of all three compounds V2, V4 and V6 in the liquid crystal

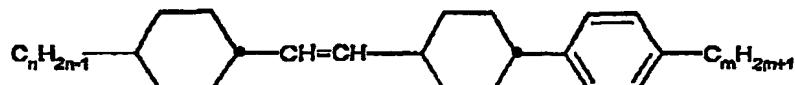
composition.

Preferably, in formula VI R⁶¹ is straight-chain alkenyl, especially straight-

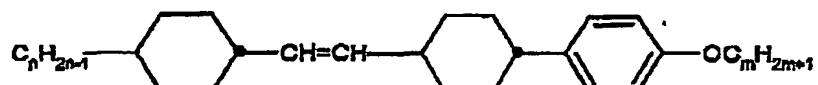
25 chain alkenyl having 2, 3, 4 or 5 carbon atoms, and R⁶² is straight-chain

alkanyl or alkoxy both having 1, 2, 3, 4 or 5 carbon atoms (formula VIA or

VIB with n = 1, 2, 3, 4, 5 and m = 1, 2, 3, 4, 5).

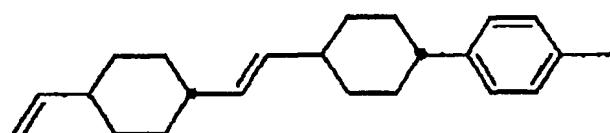


VIA

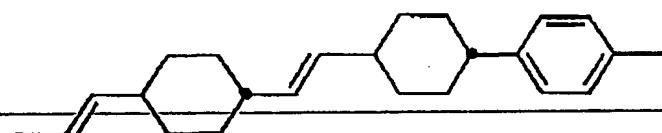


VIB

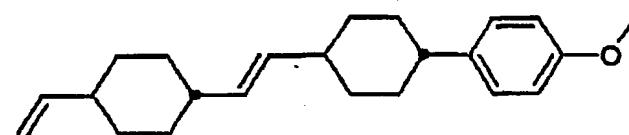
Preferred compounds of formula VI are compounds of formula VI1 to VI4:



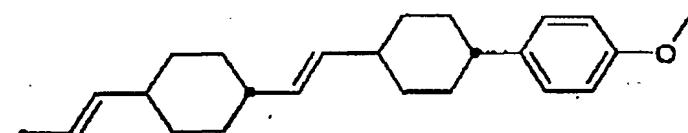
VI1



VI2



VI3

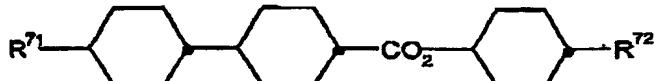


VI4

Especially preferred are compounds of formula VI1, VI3 and VI4. They may be used alone or, more preferred, as a mixture of two or three compounds.

25 Regarding compounds of formula VII specific compounds are of the following formulas

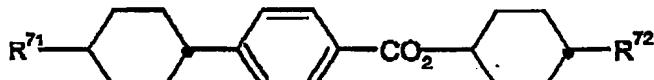
30



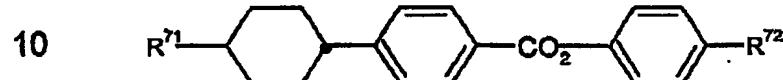
VIIA



VIIIB



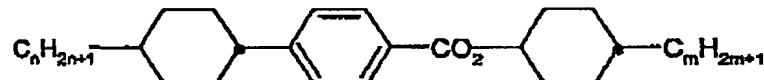
VIIC



VIID

with R^{71} and R^{72} being as defined above. Preferably, R^{71} and R^{72} are straight-chain alkyl, especially alkanyl, with 1, 2, 3, 4, 5 or 6 carbon atoms.

15 Preferred compounds of formula VII are:



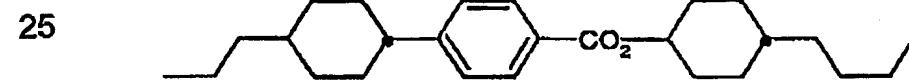
VIIC1



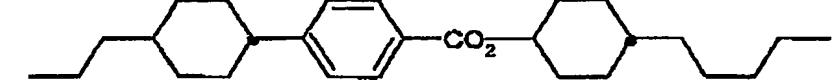
VIID1

20

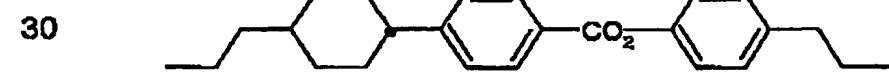
with n and m being independently of each other 1, 2, 3, 4, 5 or 6. Especially preferred examples of compounds of formula VII are



VII1



VII2



VII3



VII4

5 Component (β) is used in an amount of 5 weight% or more in the liquid crystal composition comprised in the zenithal bistable nematic devices according to the invention. When component (α) comprises at least one compound of formula II, it is preferred that the liquid crystal composition comprises 8 weight% or more of component (β). When there is no

10 compound of formula I in component (α), an amount of at least 10 weight% of component (β) is even more preferred. In certain embodiments of the invention a total amount of 15 or 20 weight% or more of component (β) is highly preferred.

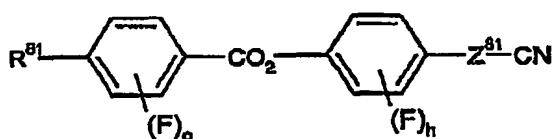
15 In an actual embodiment of the invention component (β) may contain one or more compounds of only one of the formulas III or IV or V or VI or VII. It is also possible that it contains one or more compounds of two, three or more of the formulas III to VII. It may contain an equal or a different amount of compounds of each formula used. It is preferred that component (β) contains one or more compounds of one or two of the formulas III, IV, V, VI or VII. If compounds of two of the formulas III to VII are contained, any combination is possible, i.e. III+IV or III+V or III+VI or III+VII or IV+V or IV+VI or IV+VII or V+VI or V+VII or VI+VII; both types of compounds may be used in an equal amount, or one of the types may be used in an excess with regard to the other one, for instance, in a ratio of 2:1. It is preferred that an equal amount of both types of compounds is used. In case that compounds of two of the formulas III, IV, V, VI and VII are contained in component (β), it is also preferred that one type of the compounds is of formula III. Thus, especially preferred combinations are III+IV, III+V, III+VI and III+VII. When component (α) comprises at least one compound of formula II, it is preferred that component (β) comprises compounds of two of the formulas III, IV, V, VI and VII.

It will be acknowledged that other compounds than those of formulas I and II may be present in component (a) as long as they have a sufficiently high dielectrical anisotropy $\Delta\epsilon$ and are not detrimental to the set of parameters as outlined above.

5

Thus, it is preferred that component (a) of the liquid crystal composition used in the zenithal bistable nematic device of the invention also comprises one or especially more compounds of formula VIII

10



VIII

in which

15

g and h are independently of each other 0, 1, 2, 3 or 4;

R⁸¹ is C₁-C₁₅ alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH₂ groups may be replaced independently of each other by -O-, -S-, -C≡C-, -CO-O-, -OC-O- such that there are no hetero atoms adjacent to each other (which means that R⁸¹ does not comprise any alkenyl radical);

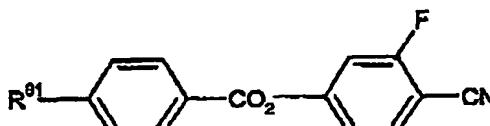
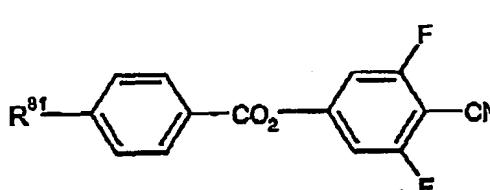
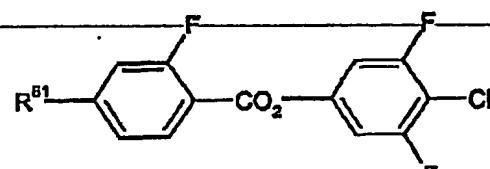
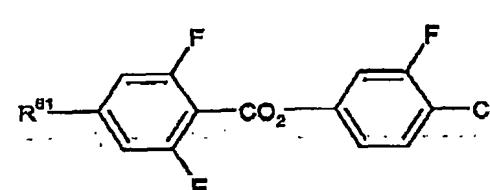
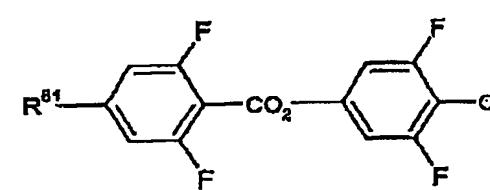
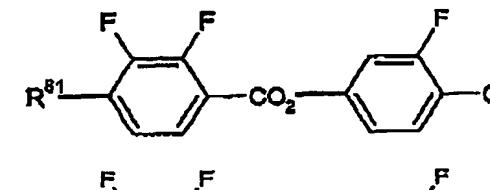
20

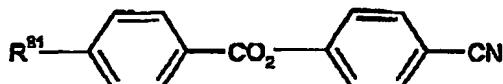
Z⁸¹ a single bond or -C≡C-.

25

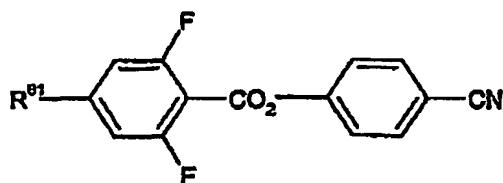
With regard to compounds of formula VIII g and h may be independently of each other 0, 1, 2, 3 or 4, preferably 0, 1 or 2; that means that preferably each of the phenyl rings of formula VIII may be unsubstituted or mono- or di-substituted with fluorine. If present the F substituent(s) may be in any position of the phenyl ring substituted. Furthermore, Z⁸¹ can be either a single bond (so that the CN group is directly linked to the phenyl ring) or a C-C triple bond thereby forming a -C≡C-CN substituent of the phenyl ring. It is preferred that Z⁸¹ is a single bond.

Preferred compounds of formula VIII are the following compounds:

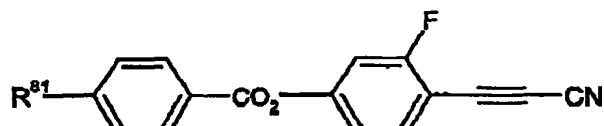
			VIIIA
5			
10			VIIIB
15			VIIIC
20			VIIID
25			VIIIE
30			VIIIF
			VIIIG
			VIIIH



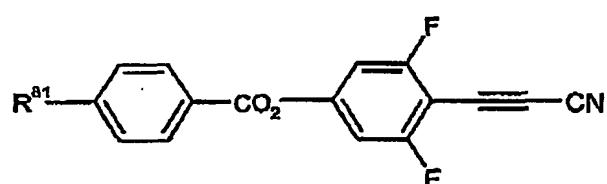
VIIIJ



VIIIK

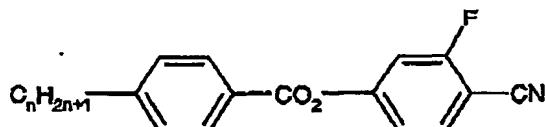


VIIIL

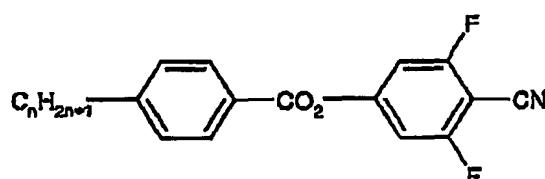


VIIIM

with R⁸¹ being defined as above. Preferably, R⁸¹ in formulas VII and VIIA to VIIIM is straight-chain alkyl, especially straight-chain alkanyl having 1, 2, 3, 4, 5, 6, 7 or 8 carbon atoms. Highly preferred compounds are of general formulas VIIIA1 and VIIIB1 with n = 1, 2, 3, 4, 5 or 6, whereby compounds of formula VIIIA1 are most preferred.

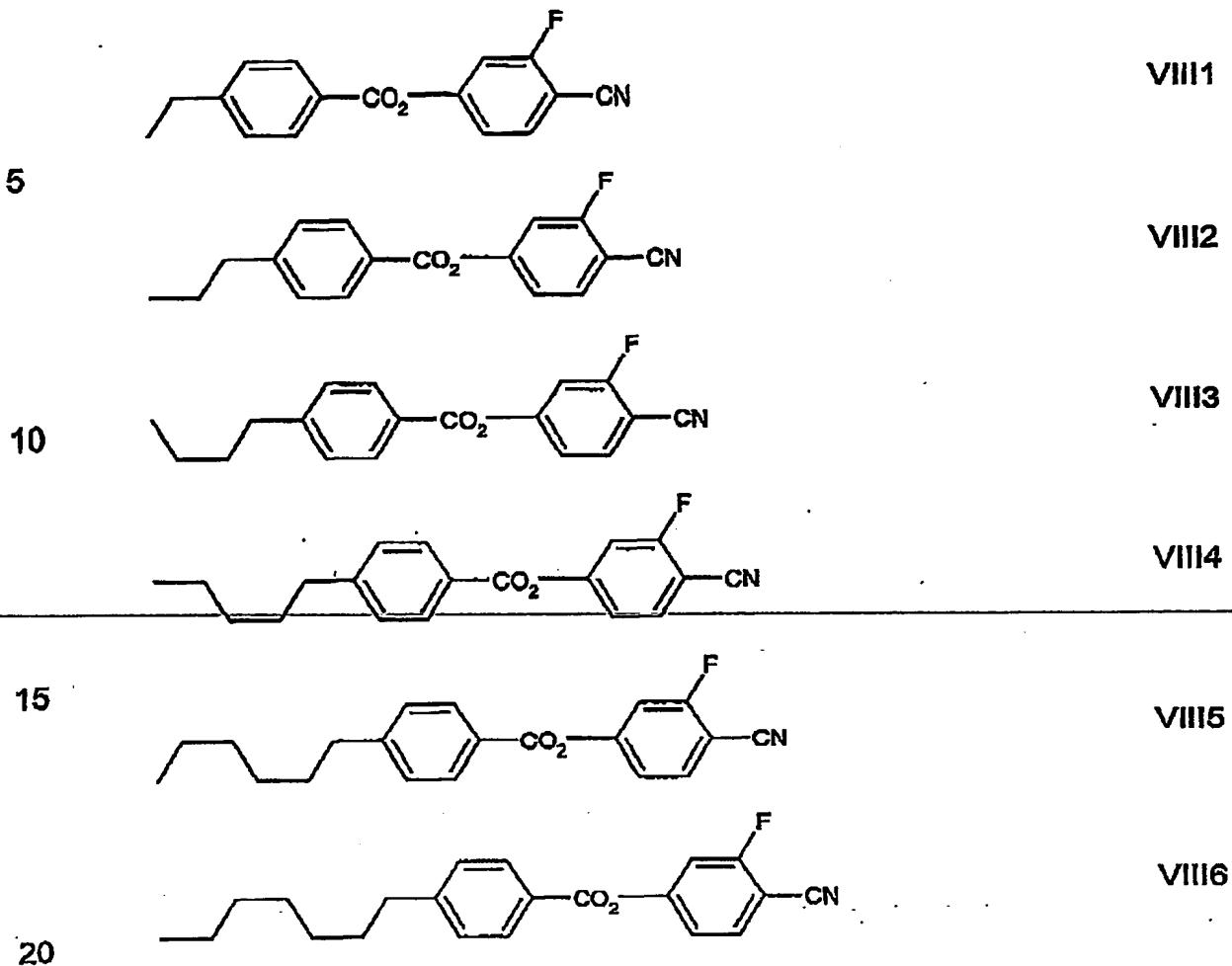


VIIIA1



VIIIB1

30 Especially preferred compounds of formula VII are compounds of formula VII1 to VII6:



Among these compounds of formulas VIII1 (having a dielectric anisotropy $\Delta\epsilon$ of 53.7), VIII2, VIII3 ($\Delta\epsilon \approx 44.9$) and VIII4 ($\Delta\epsilon = 43.0$) are most preferred. If present the total amount of compounds of formula VIII in the liquid crystal composition for use in the zenithal bistable nematic devices of the invention may be about 10 weight% or more (although even smaller amounts are possible as well), preferably 20 weight% or more, more preferred in the range of about 25 to 60 weight%, still more preferred in the range of about 35 to about 55 weight%. When used as a mixture different compounds of formula VIII may be contained in component (a) in an almost equal amount. For instance, if compounds of formulas VIII1 to VIII4 are used, they may be contained in an 1:1:1:1 ratio.

In another preferred embodiment of the invention component (a) of the liquid crystal composition for use in the zenithal bistable nematic devices comprises at least one compound of formula IX:

5

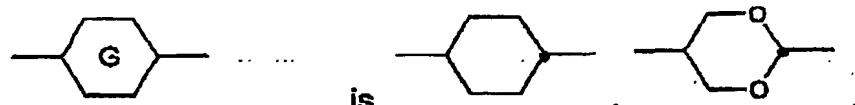


10 in which

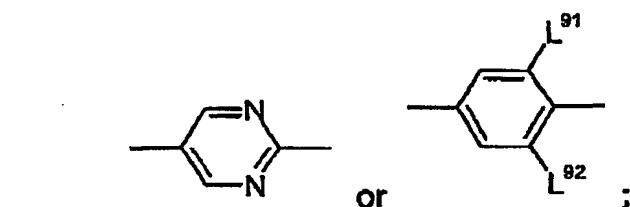
J is 0 or 1;

15 R^{91} is C₁-C₁₅ alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH₂ groups may be replaced by -O-, -S-, -CH=CH-, -C≡C-, -CO-O-, -OC-O- such that there are no hetero atoms adjacent to each other;

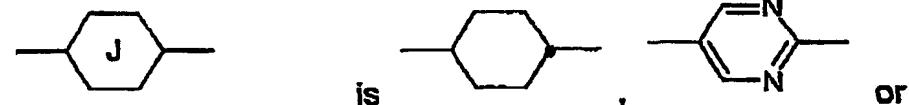
Z⁹¹ and Z⁹² are independently of each other a single bond or -C≡C-;



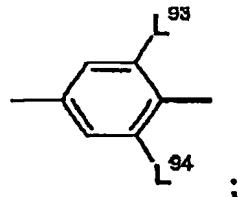
20



25



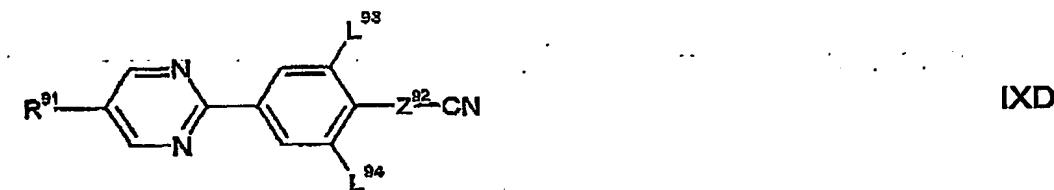
30



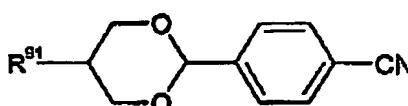
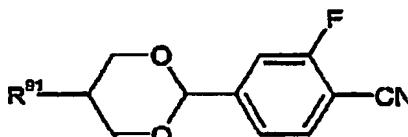
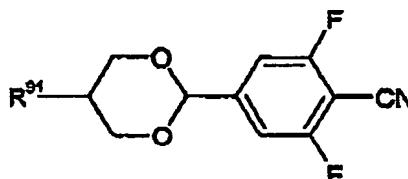
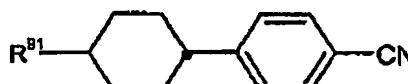
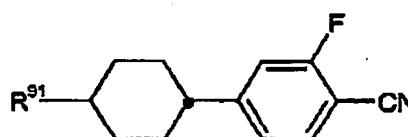
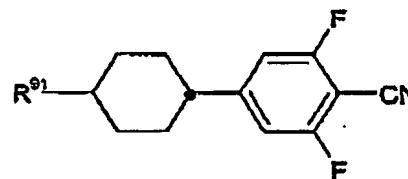
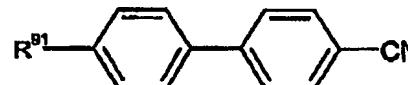
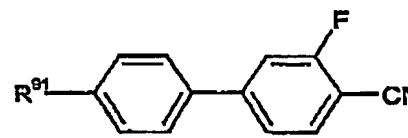
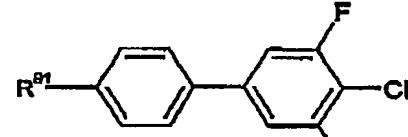
in which

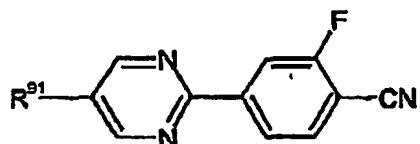
L^{91} , L^{92} , L^{93} and L^{94} are independently of each other H or F.

Preferred classes of compounds comprised by formula IX are compounds
5 of formula IXA to IXE in which Z^{91} is a single bond:

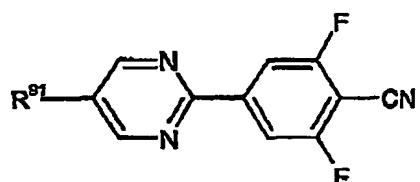


in which R^{91} is defined as above and preferably means a straight-chain alkyl with 1 to 8 carbon atoms, especially a straight-chain alkanyl or alkenyl having 2, 3, 4, 5 or 6 carbon atoms; Z^{92} is a C-C triple bond or preferably a single bond; and L^{91} , L^{92} , L^{93} and L^{94} are H or F with L^{91} and L^{92} being preferably H. Preferred compounds of formulas IXA to IXE are

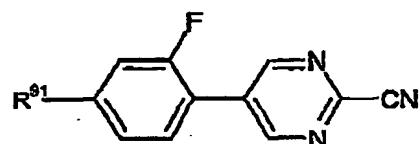
		IXA1
5		IXA2
10		IXA3
		IXB1
15		IXB2
20		IXB3
		IXC1
25		IXC2
30		IXC3



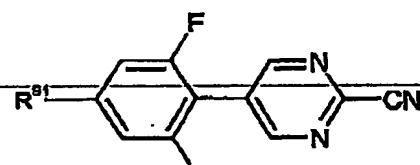
IXD1



IXD2



IXE1

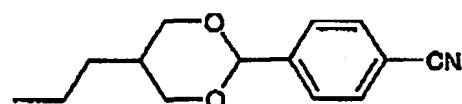


IXE2

in which R^{91} is as defined above.

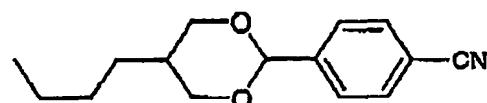
Some specific examples of compounds of formula IX are

20

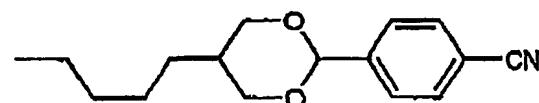


IX1

25

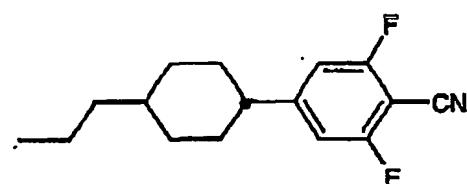


IX2



IX3

30

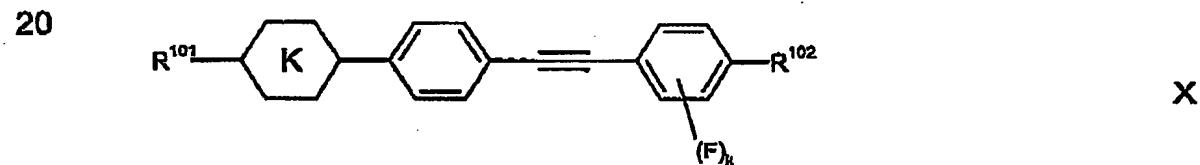


IX4

5 If these compounds are present in component (a) their total amount may range from about 5 to about 45 weight%. It is preferred that only one type of compounds of formulas IXA to IXE are present in the liquid crystal composition for use in the invention for the same time.

10 In another preferred embodiment of the invention the liquid crystal composition for use in the bistable liquid crystal device and especially in the zenithal bistable nematic device according to the invention further comprises 3 weight% or more of a component (y) containing one or more compounds having an optical anisotropy Δn of at least 0,20. It has been found that the use of this component (y) may decrease the operating voltage V_{opt} of the liquid crystal composition. In general, component (y) can comprise any (mesogenic) compound exhibiting a Δn of at least 0,20 that is not detrimental to the set of parameters important for use in zenithal bistable nematic liquid crystal devices. It is preferred that component (y) comprises tolanes having a Δn of at least 0,20, especially at least one tolane compound of formula X:

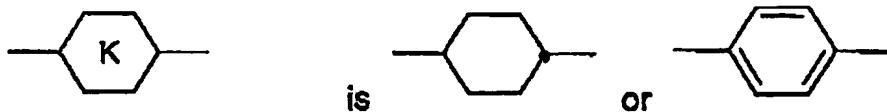
15



25 in which

k is 0, 1, 2, 3 or 4;

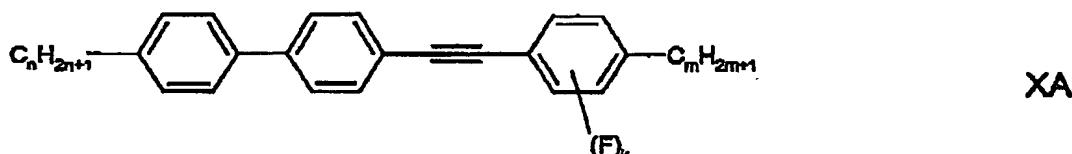
30 R^{101} and R^{102} are independently of each other C₁-C₁₅ alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH₂ groups may be replaced by -O-, -S-, -CH=CH-, -C≡C-, -CO-O-, -OC-O- such that there are no hetero atoms adjacent to each other; and



5

Preferred are compounds of formula XA

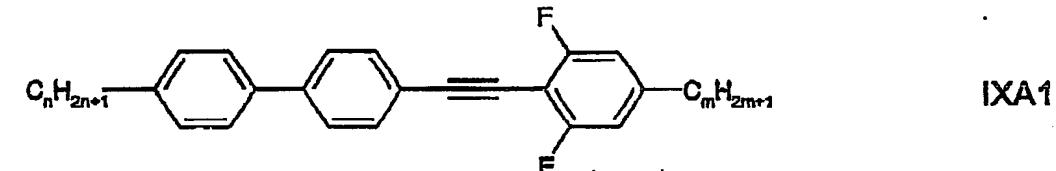
10



in which n and m are independently of each other 1, 2, 3, 4, 5 or 6 and k is 0, 1 or preferably 2. Preferred examples are of formula IXA1 with n being 2, 3 or 4 and m being 1, 2, 3, 4 or 5:

15

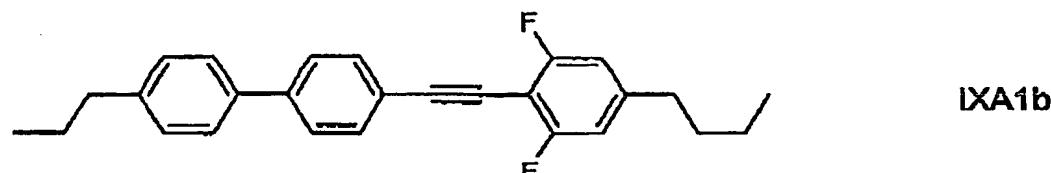
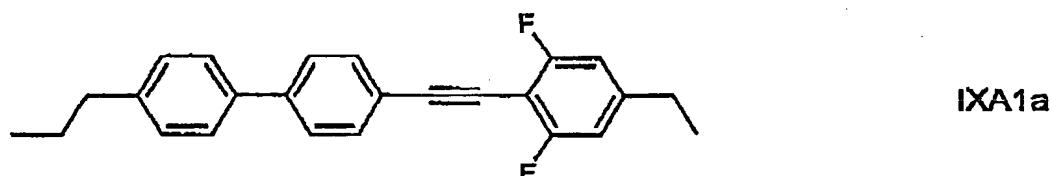
20



25

30

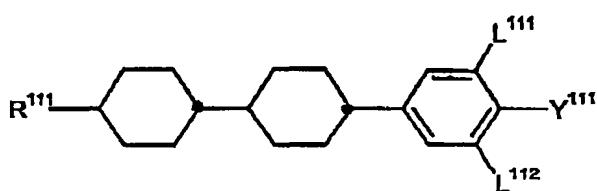
Among these compounds IXA1a and IXA1b are most preferred:



If present component (y) is contained in an amount of at least 3 weight%, preferably at least 5 weight%.

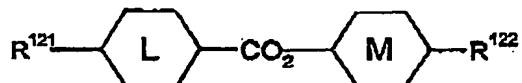
5 The liquid crystal composition for use in the bistable liquid crystal devices and especially in the zenithal bistable nematic liquid crystal devices of the invention may comprise further substances for adjusting several properties of said composition if desired. For example, some of these substances may be used for adjusting the viscosity of the liquid crystal composition. In
10 certain embodiments the liquid crystal composition for use in the zenithal bistable nematic devices according to the invention comprises at least one compound of formula XI and/or at least one compound of formula XII and/or at least one compound of formula XIII and/or at least one compound of formula XIV

15

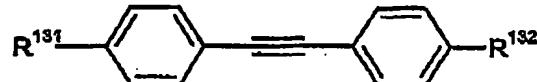


XI

20



XII



XIII

25



XIV

in which

30

R^{111} and R^{142} are independently of each other C_2-C_{15} alkenyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced independently of each other by -O-, -S-, -CH=CH-, -C≡C-, -CO-O-, -OC-O- such that there are no hetero atoms adjacent to each other;

5

R^{121} , R^{131} , R^{132} and R^{141} are independently of each other C_1-C_{15} alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced independently of each other by -O-, -S-, -CH=CH-, -C≡C-, -CO-O-, -OC-O- such that there are no hetero atoms adjacent to each other;

10

R^{122} is C_1-C_{15} alkyl which is unsubstituted or mono- or poly-substituted with halogen and in which one or more of the CH_2 groups may be replaced independently of each other by -O-, -S-, -CH=CH-, -C≡C-, -CO-O-, -OC-O- such that there are no hetero atoms adjacent to each other;

15

Y^{111} is F, Cl, C_1-C_{15} alkanyl which is mono- or poly-substituted with halogen, or C_1-C_{15} alkoxy, which is mono- or poly-substituted with halogen;

20

L^{111} and L^{112} are independently of each other H or F; and

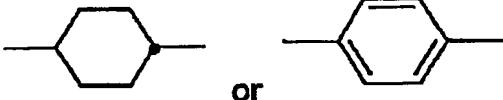


and



are independently of each other

25

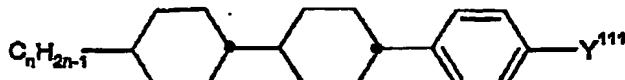


or

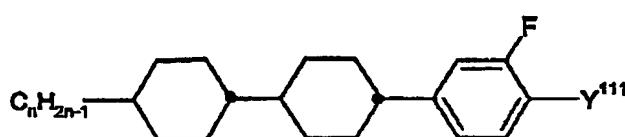
30 The exact nature and amount of these compounds within the liquid crystal composition depend on the specific mixture and the desired effect and can be easily chosen by the skilled person.

Preferred compounds of formula XI are compounds of formula XIA or XIB

5



XIA

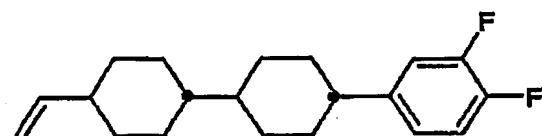


XIB

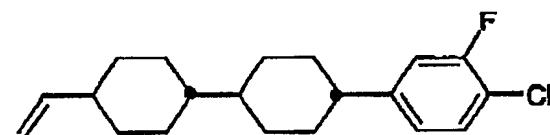
10

with n being 2, 3, 4, 5 or 6 and Y^{111} being selected from F, Cl, CF_3 and OCF_3 . Especially preferred compounds of formula XI are the following compounds:

15

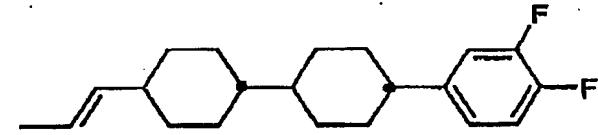


XI1



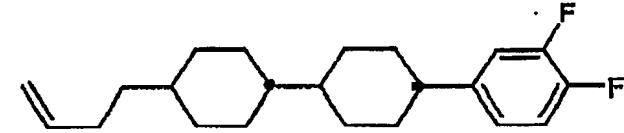
XI2

20



XI3

25

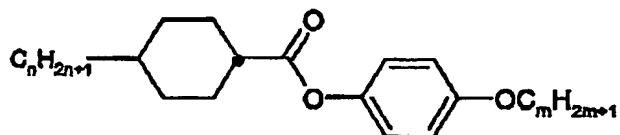


XI4

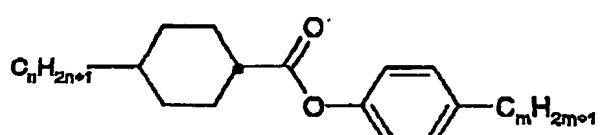
The most preferred compound of formula XI is compound XI1.

30

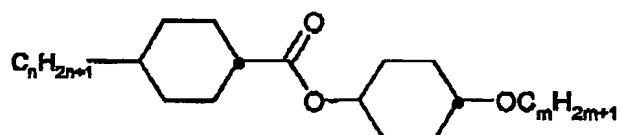
Preferred compounds of formula XII are compounds of formula XIIA, XIIB, XIIC, XIIID, XIIE and XIIF:



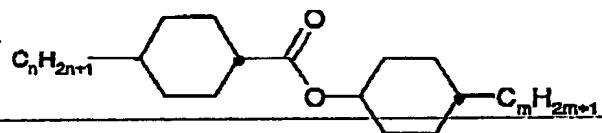
XIIA



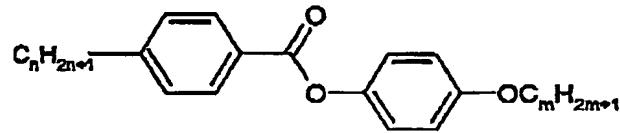
XIIB



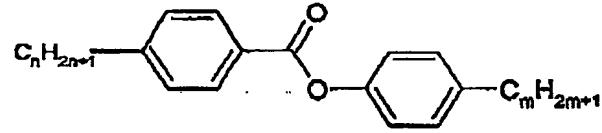
XIIC



XIID

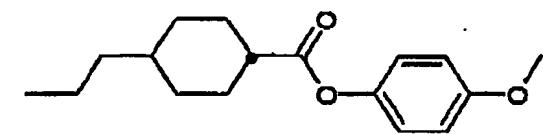


XIIE

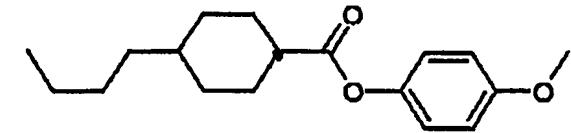


XIIF

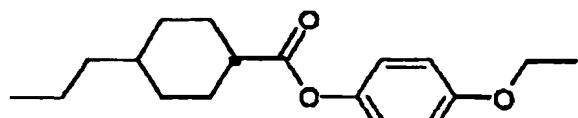
with n being 1, 2, 3, 4, 5 or 6 and m being 1, 2, 3, 4, 5 or 6. Specific examples of compounds of formula XII are the following compounds:



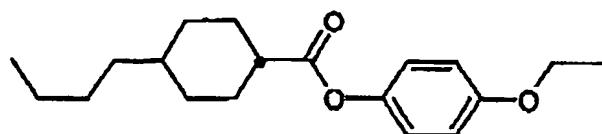
XII1



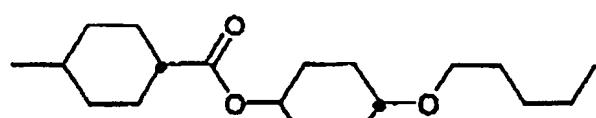
XII2



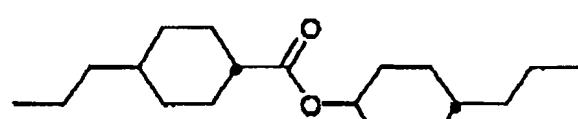
XII3



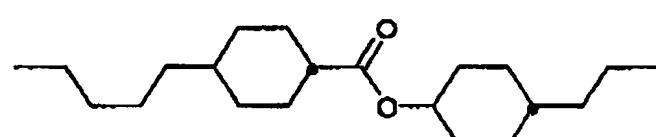
XII4



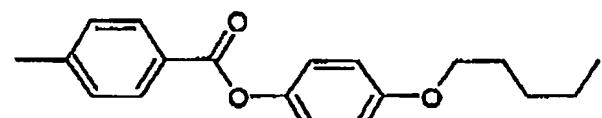
XII5



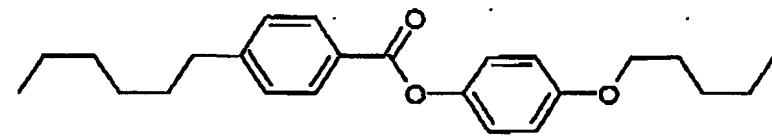
XII6



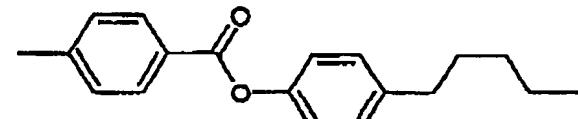
XII7



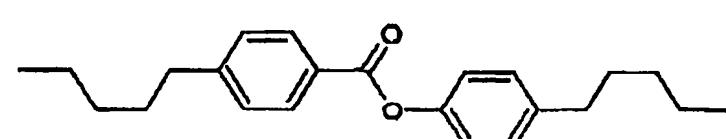
XII8



XII9

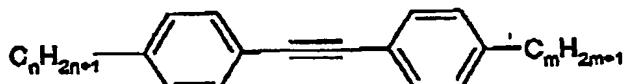


XII10



XII11

30 Preferred compounds of formula XIII are compounds of formula XIII A or XIII B:



XIIIA



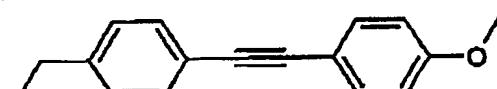
XIIIB

with n being 1, 2, 3, 4, 5, 6, 7 or 8 and m being 1, 2, 3, 4, 5 or 6. Especially preferred examples of compounds of formula XIII are the following

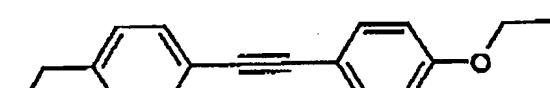
10 compounds:



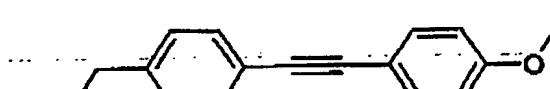
XIII1



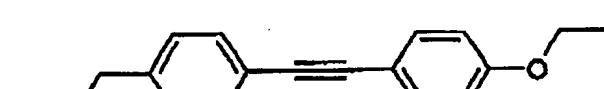
XIII2



XIII3



XIII4

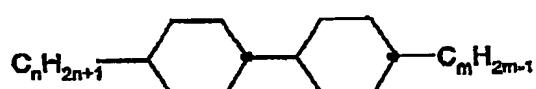


XIII5



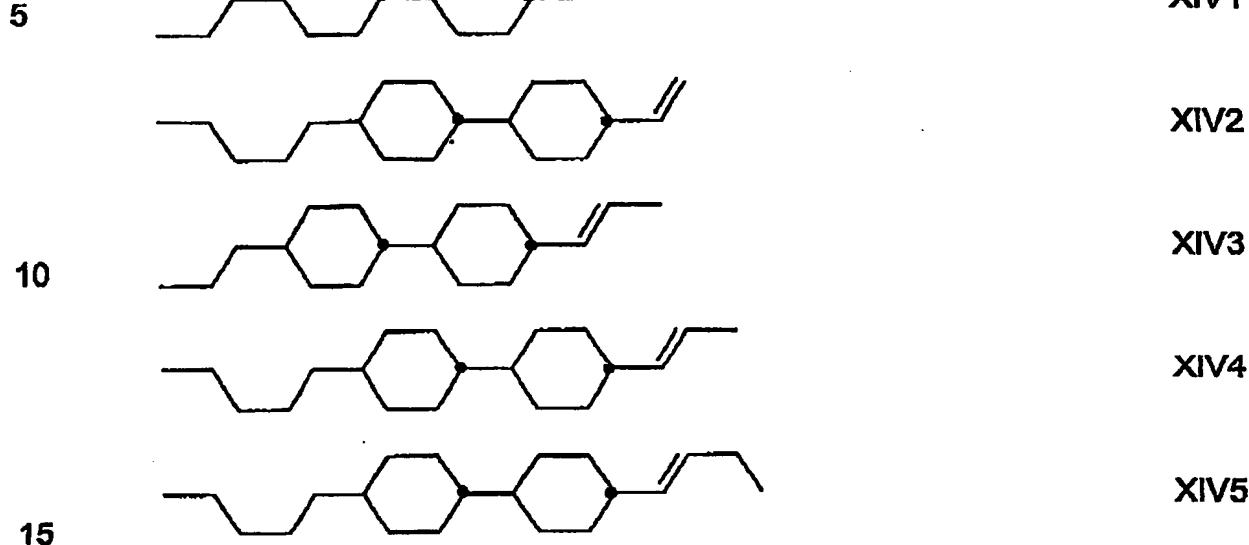
XIII6

Preferred compounds of formula XIV are compounds of formula XIVA



XIVA

with n being 1, 2, 3, 4, 5, 6, 7 or 8 and m being 2, 3, 4, 5 or 6. Specific examples of compounds of formula XIV are the following compounds:



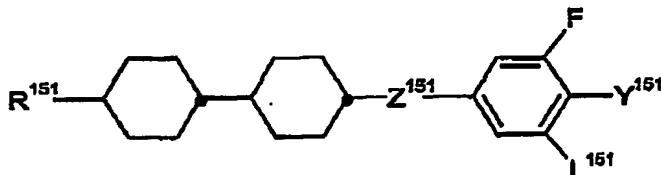
The most preferred compound of formula XIV is compound XIV2.

The liquid crystal composition for the use according to the invention in the zenithal bistable nematic liquid crystal devices may also comprises mesogenic substances having a medium dielectric anisotropy of $\Delta\epsilon$ of about 8 to 10 or more, for instance one or more compounds of formula XV and/or one or more compounds of formula XVI, preferably in an amount of up to 30 weight%, more preferred of up to 20 weight%:

25

30

5



XV

10

in which

R^{151} and R^{161} are independently of each other C_1-C_{15} alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen

15

and in which one or more of the CH_2 groups may be replaced independently of each other by $-O-$, $-S-$, $-CH=CH-$, $-C\equiv C-$, $-CO-O-$, $-OC-O-$ such that there are no hetero atoms adjacent to each other;

20

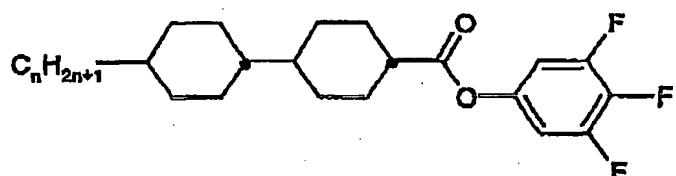
Y^{151} and Y^{161} are independently of each other F, Cl, C_1-C_{15} alkanyl which is mono- or poly-substituted with halogen, or C_1-C_{15} alkoxy, which is mono- or poly-substituted with halogen;

25

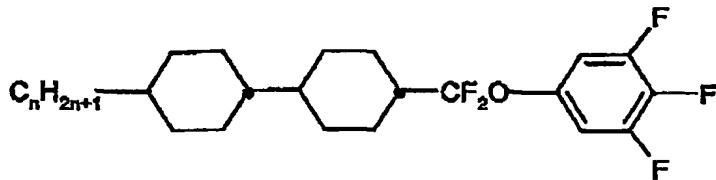
L^{151} and L^{161} are independently of each other H or F; and Z^{151} is $-CO-O-$, CH_2O or CF_2O .

Preferably these compounds are of formulas XVA, XVB and XVIa, respectively:

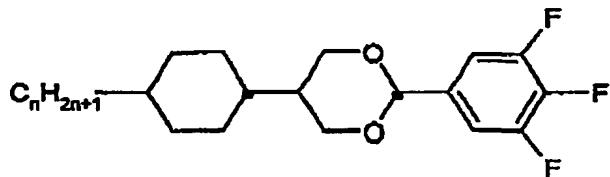
30



XVA



XVIB



XVIA

10 with n being in all three formulas 1, 2, 3, 4, 5, 6 or 7. These substances may influence both the operating voltage and the operating window of the liquid crystal composition for use in the zenithal bistable nematic devices of the invention as desired.

15 It is further preferred that the liquid crystal composition for the use of the invention is a nematic liquid crystal composition.

It will be acknowledged by those skilled in the art that the liquid crystal composition for the use according to the invention may also comprise further (mesogenic) compounds besides those disclosed in more detail in this specification. A wide variety of mesogenic compounds may be used as long as they are not detrimental to the set of parameters important for the use of the bistable liquid crystal composition according to the invention.

25 A further subject matter of the present invention is a liquid crystal medium comprising

- at least one compound of formula I as defined above; and
- at least one compound of formula III and/or at least one compound of formula IV and/or at least one compound of formula V and/or at least one compound of formula VI and/or at least one compound of formula VII all being as defined above.

Said medium optionally comprises at least one compound of formula VIII as defined above.

Still a further subject matter of the present invention is a liquid crystal medium comprising

- 5 - at least one compound of formula II as defined above; and
- at least one compound of formula III and/or at least one compound of formula IV and/or at least one compound of formula V and/or at least one compound of formula VI and/or at least one compound of formula VII all being as defined above.

10 Said medium optionally comprises at least one compound of formula VIII as defined above.

15 The liquid crystal composition for use in the zenithal bistable nematic devices of the invention may also contain an optically active component (ζ) as a dopant in an amount of 0 to 3 weight%. The chiral dopant may be useful to remove reverse twist domains in the TN mode. There exists a wide variety of compounds suitable as members of component (ζ) all of which are readily available. Exemplary substances are

20 cholesterylnonanoate (CN), S-811, S-1011 and S-2011 and CB15 (Merck KGaA, Darmstadt, Germany). Although S-811 might be a preferred dopant, the specific choice of the dopants is not a critical issue.

25 The liquid crystal composition for use in the zenithal bistable nematic devices of the invention may also contain one or more light stabilizers and/or additives like pleochromatic dyes known in the state of the art.

30 All the compounds used in the liquid crystal composition of the bistable liquid crystal devices are either commercially available or can be readily prepared by methods known to those skilled in the art and as described in the standard text books of organic synthesis, for instance, in Houben-Weyl, *Methoden der Organischen Chemie*, Georg-Thieme-Verlag, Stuttgart. The

liquid crystal composition will be prepared by applying standard protocols and techniques. In general, the desired amount of the minor component(s) will be dissolved in the major component, usually under elevated temperature. Alternatively, solutions of components in organic solvents like acetone, chloroform or methanol, can be mixed and afterwards the solvent(s) can be removed, e.g., by distillation. Likewise, manufacturing of the bistable devices according to the invention will follow standard techniques known to the artisan.

5 In the present description and the following examples the structures of the mesogenic compounds disclosed are described by using acronyms. Said acronyms can be transformed into chemical formulas according to Tables A and B. In these tables, radicals C_nH_{2n+1} and C_mH_{2m+1} are straight-chain alkyl radicals having n and m carbon atoms, respectively. Alkenyl radicals have the trans configuration. The codes according to Table B are self-evident. In Table A, only the acronym for the parent structure is given. In individual cases, the acronym for the parent structure is followed, usually separated by a hyphen, by a code for the substituents R^1 , R^2 , L^1 and L^2 as given below:

10

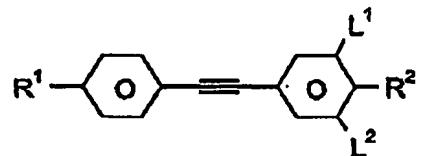
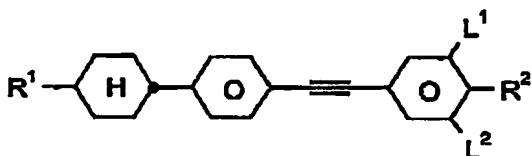
Code of R^1 ,	R^1	R^2	L^1	L^2
	R^2 , L^1 , L^2			

15

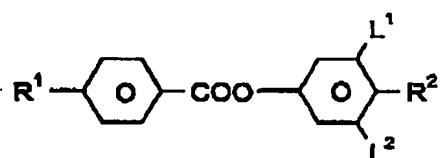
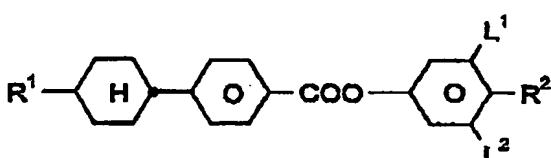
n	C_nH_{2n+1}	CN	H	H
nm	C_nH_{2n+1}	C_mH_{2m+1}	H	H
nOm	C_nH_{2n+1}	OC_mH_{2m+1}	H	H
nF	C_nH_{2n+1}	F	H	H
nN.F	C_nH_{2n+1}	CN	F	H
nN.F	C_nH_{2n+1}	CN	F	H
30 nN.F.F	C_nH_{2n+1}	CN	F	F

Table A:

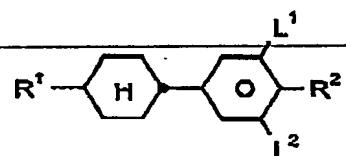
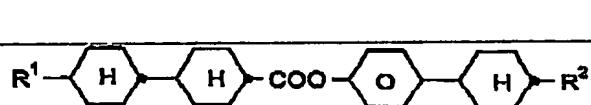
5

**PTP****CPTP**

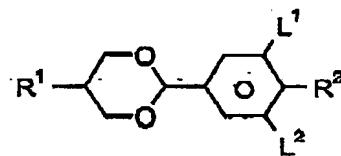
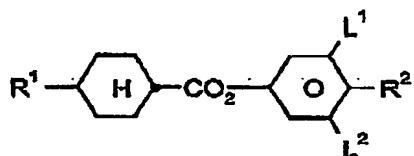
10

**ME****HP**

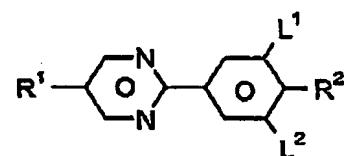
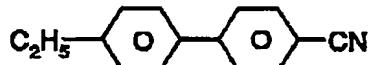
15

**PCH****CCPC**

20

**PDX****D**

25

**PYP****K6**

30

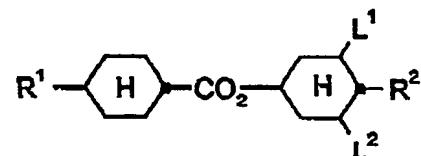
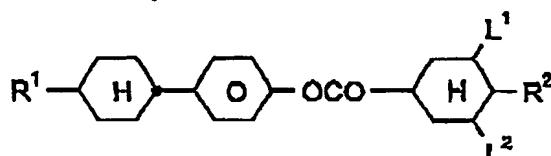
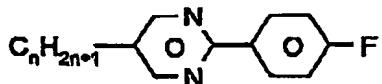
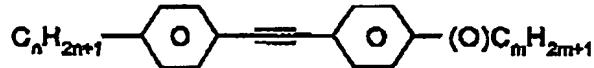
**OS****HD**

Table B:

5		CBC-nm
10		CBC-nmF
15		CP-nm
20		CP-nmF
		CC-n-V
		CCG-V-F
25		CCP-Vn-m
30		CCP-V-m
		PZU-V2-N

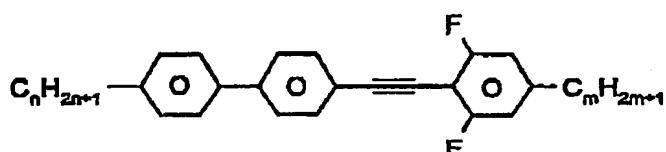


PYP-nF



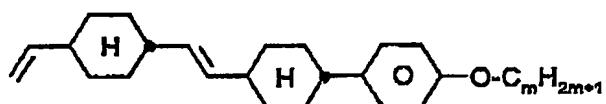
PTP-n(O)m

5



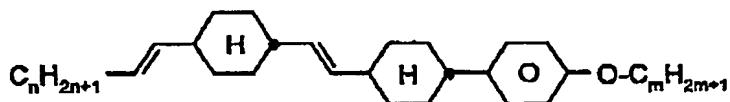
10

PPTUI-n-m



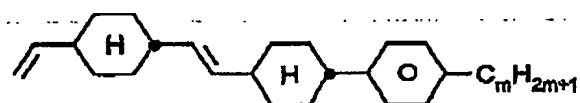
CVCP-V-Om

15

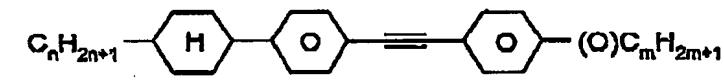
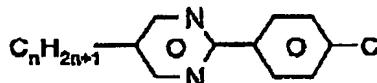


CVCP-nV-Om

20



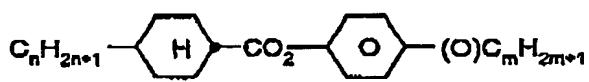
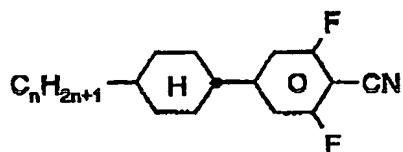
CVCP-V-m



25

PYP-n

CPTP-n(O)m



30

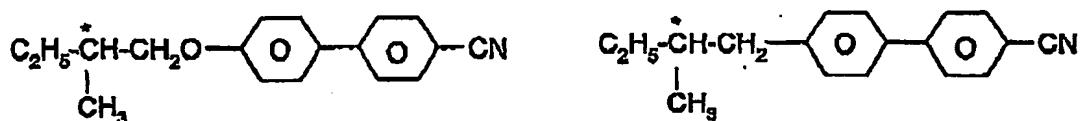
PCH-nN.F.F

D-n(O)m

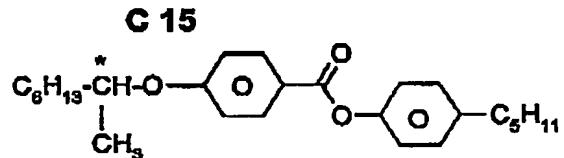
Table C:

Table C shows dopants optionally present in the liquid crystal compositions for use in the zenithal bistable nematic devices of the invention (component (ζ)).

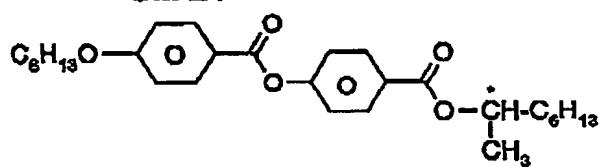
5



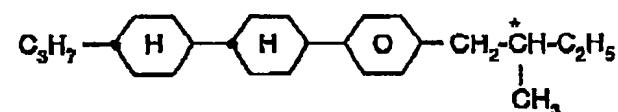
10

**CB 15**

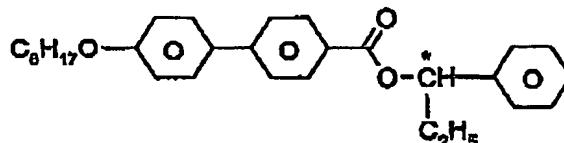
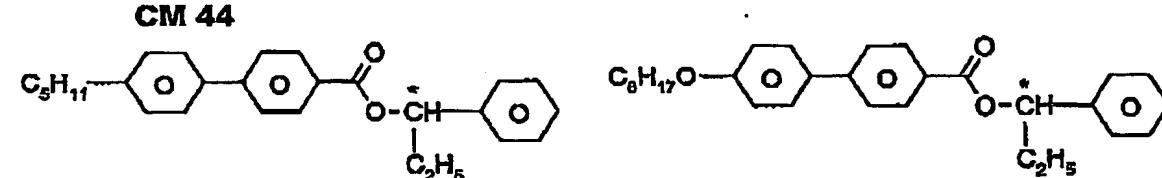
15



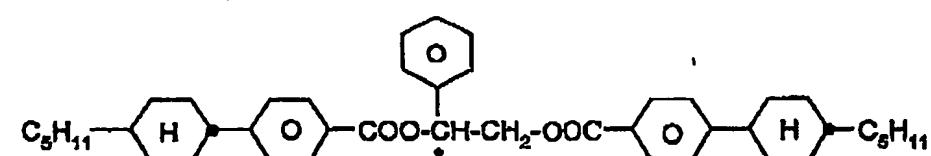
20

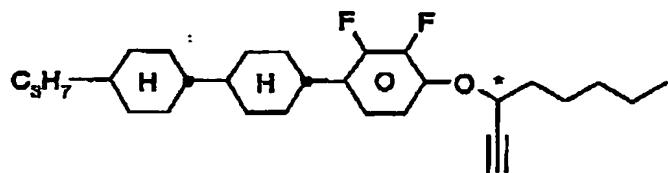


25



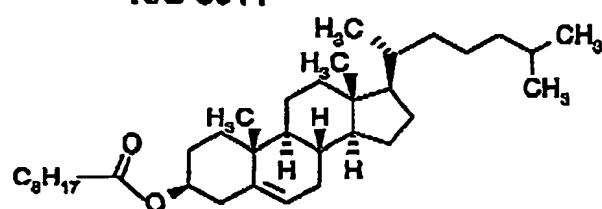
30

**R/S-1011**



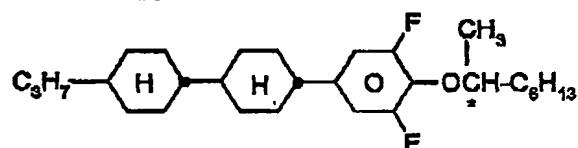
5

R/S-3011



10

CN



R/S-2011

15

20

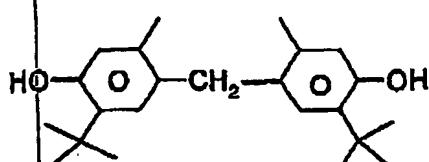
25

30

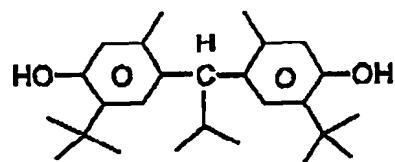
Table D:

Table D shows stabilizers optionally present in the liquid crystal compositions for use in the zenithal bistable nematic devices of the invention.

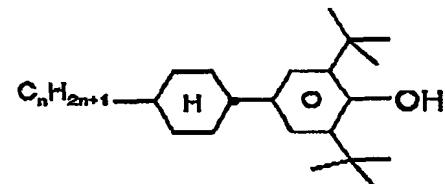
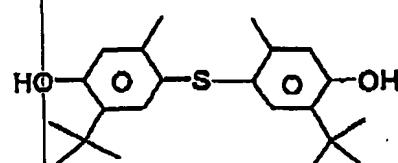
5



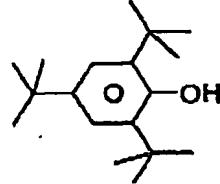
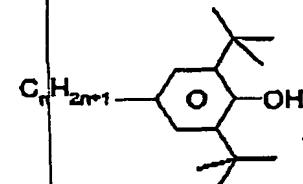
10



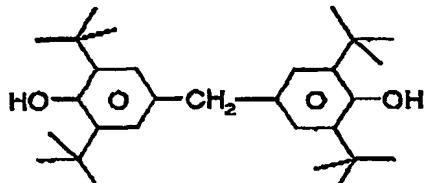
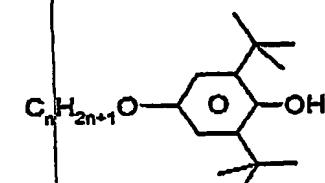
15



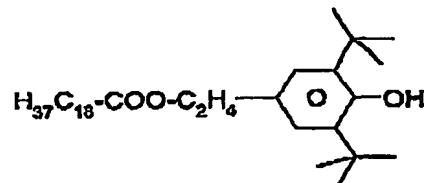
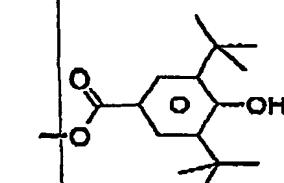
20

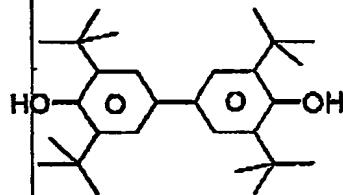


25

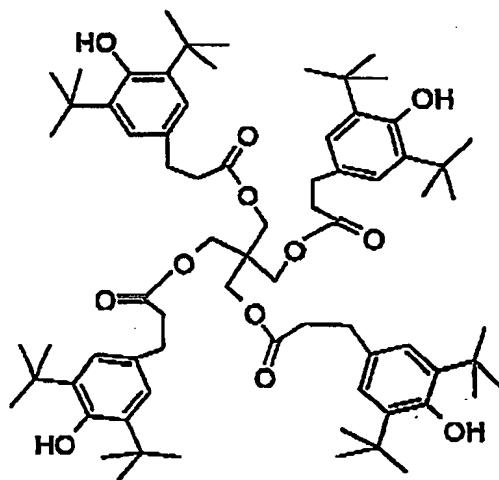


30

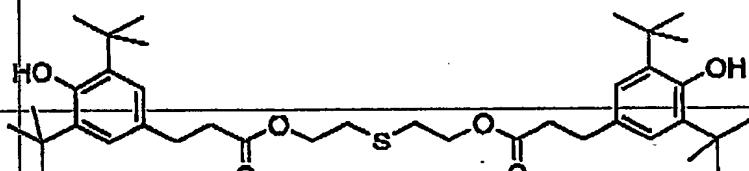




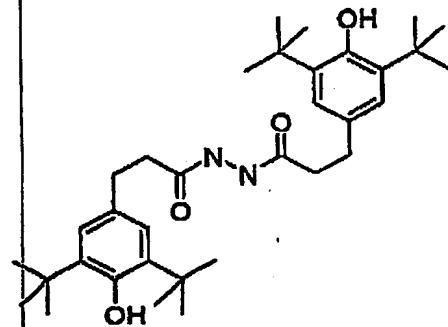
5



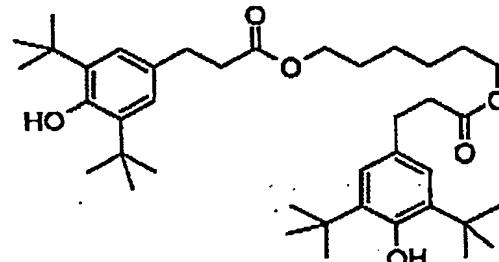
10



15



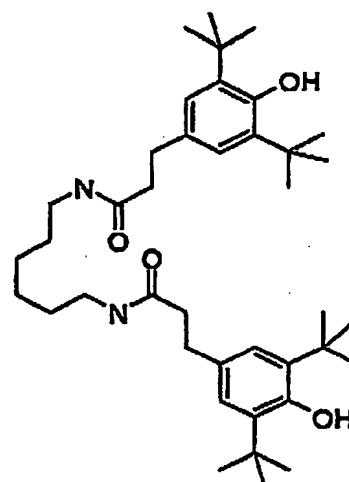
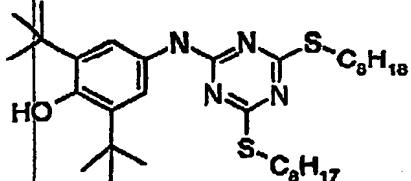
20



25

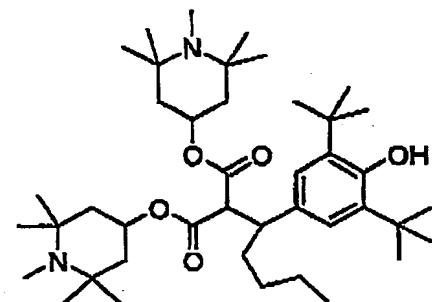
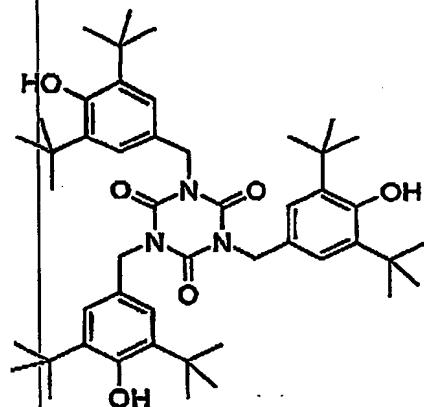
30

5

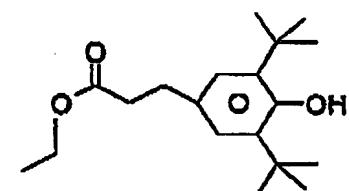
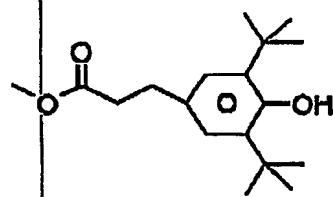


10

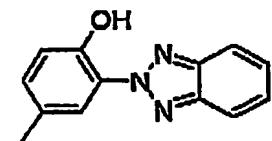
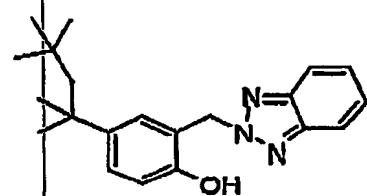
15



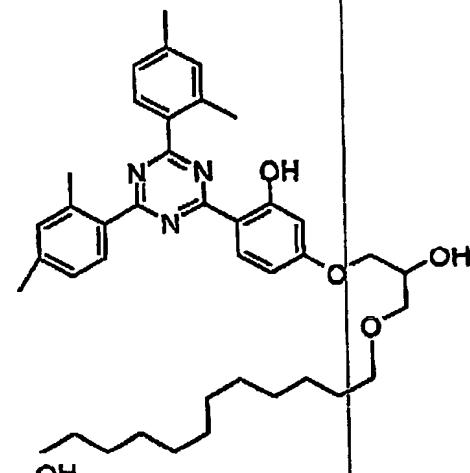
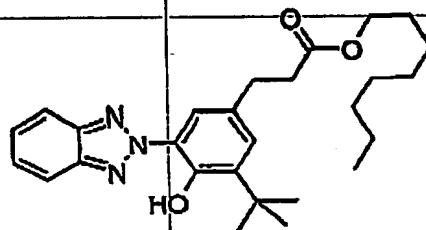
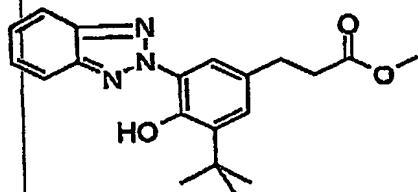
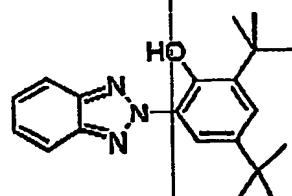
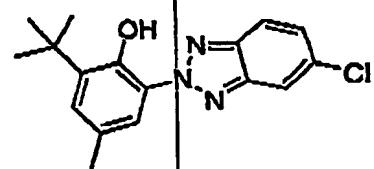
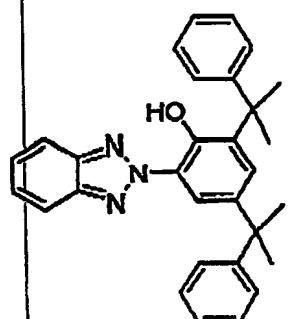
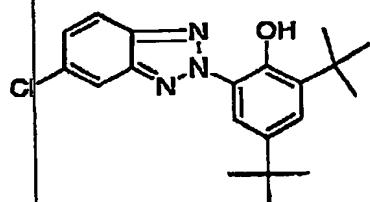
20



25

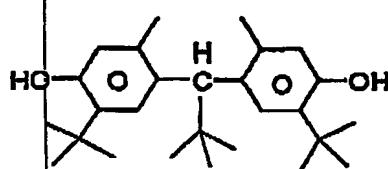
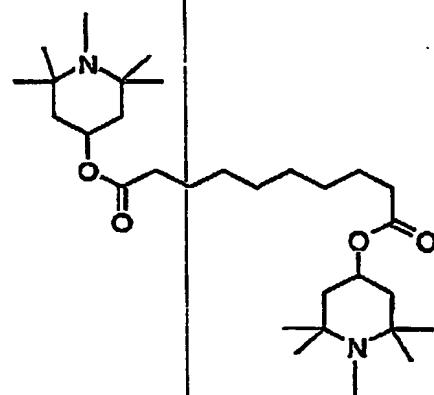
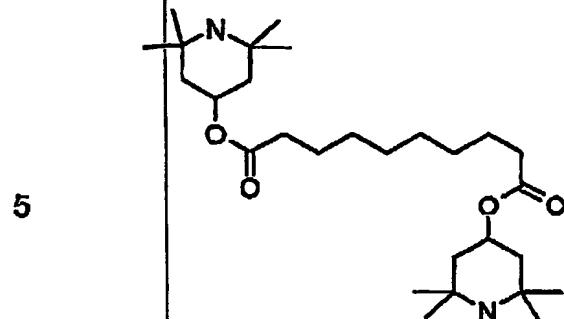


30



25

30



15

20

25

30

Percentages given herein are weight% and generally related to the total amount of a composition or mixture except stated otherwise. Temperatures are given in degree Celsius (°C) unless stated otherwise. T_{NI} means the clearing point at which a nematic medium becomes isotropic. Δn is the

5 optical anisotropy (birefringence) (at 589 nm, 20 °C). $\Delta \epsilon$ means the dielectric anisotropy (at 1 kHz, 20 °C). K_1 is the splay elastic constant, and K_3 is the bend elastic constant both given in pN. Electrooptical data has been determined in a VAN zenithal bistable nematic cell. Except stated otherwise the measurements have been performed at 20 °C. V_{opt} is the

10 corrected operating voltage (in V) derived from the corrected switching field $E_{LC@100\mu s}$ (at 25 °C; in zenithal bistable test cells with the actual cell gap d of about 2.8 to about 5 μm ; 100 μs pulse) by $V_{opt} = E_{LC@100\mu s} \cdot d_{opt}$ (with d_{opt} (in μm) being $\lambda\sqrt{3}/(2\Delta n)$; $\lambda = 555$ nm), ΔV_{opt} is the corrected operating

15 window at a 400 μs pulse for B-W-switching and reverse switching (in V); it is calculated from the experimental switching field window $\Delta E_{LC@400\mu s}$ (at 25 °C; 400 μs pulse) multiplied with d_{opt} defined as given above. Optical response time τ_{opt} (in ms) is calculated from $\tau_{opt} = \tau \cdot d_{opt}^2/d^2$ with τ being the experimental response time, d_{opt} being as defined above and d being the experimental cell gap.

20 The following Examples should further illustrate the present invention as described above and in the claims but not meant to restrict its scope.

25

30

Examples

Test samples were prepared by weighing out the appropriate weight amounts (percentage weight/weight) of the individual components. The sample was then homogenised by heating into the isotropic phase and thoroughly mixing. The mixture was then stirred with a given concentration of alumina and then filtered ($0.2\mu\text{m}$) to just leave the liquid crystal mixture. The nematic to isotropic transition temperature (or clearing point, T_{NI}), dielectric anisotropy ($\Delta\epsilon$), birefringence (Δn), splay and bend elastic constants (K_1 and K_3), and rotational viscosities (γ_1) were determined as described in the Merck brochure "Physical Properties of Liquid Crystals – Description of the measurement methods", ed. W. Becker (1998). Values for single compounds are extrapolated from those determined using a known concentration (usually 10 weight% of the single compound) in a standard host mixture for which the initial mixture values are also known. The electrooptical performance of each mixture in a zenithal bistable nematic device was measured using a simple experimental set-up and the VAN type test cells. This required a transmissive mode microscope with a mounted photo-detector connected to an oscilloscope. This allowed the transmission through crossed polarisers to be monitored. The test cell was mounted on a heating stage under the microscope to permit measurements at 25°C . Bipolar electrical pulses (of varying duration and voltage) were used to ensure that there was no net d.c. voltage applied to the cell. The trailing edge (and so polarity) of each pulse therefore determined the final switched state (depending on the duration and voltage). Two signal generators were necessary to ensure that the correct initial state is first selected, with the first signal triggering the second (with an appropriate phase difference). Both signals were amplified by passing the output of the signal generators through an amplifier before being connected to the test cell. For the B-W transition, the voltages required for 10 and 90% transmission changes and reverse 90 and 10% transmission changes were

measured for various pulse durations. For the W-B transition, the voltages required for 90 and 10% transmission changes only were measured for various pulse durations. These levels were set on the oscilloscope once the 0 and 100% transmission levels were known (i.e. black and white), and 5 they could also be used to determine the optical response time of the transition (for 10 to 90% transmission changes).

10 VAN type test cells were used with cell gaps typically 3-5 μ m, in transmissive mode and with crossed polarisers. Due to the varying cell thicknesses and different mixture Δn values, the retardation was not optimised but this is not crucial as it only decreases the contrast.

15

20

25

30

Example 1

5

10

15

Compound	Amount (wt%)	T_{NI} (°C)		92.4
ME2N.F	12	Δε		43.7
ME3N.F	12	Δn		0.1428
ME4N.F	12	K ₁ (pN)		7.6
ME5N.F	12	K ₃ (pN)		22.5
HP-3N.F	5	V _{opt} (V)		11.4
HP-4N.F	5	ΔV _{opt} (V)		7.3
HP-5N.F	5	τ _{opt} (ms)		55
CC-5-V	10	γ ₁ (mPa.s)		448
CCG-V-F	15			
CCPC-33	4			
CCPC-34	4			
CCPC-35	4			
<i>Total</i>	100			

20

25

30

Example 2

Compound	Amount (wt%)	T_{NI} (°C)		82.6
ME2N.F	12	Δε		43.4
ME3N.F	12	Δn		0.1465
ME4N.F	12	K ₁ (pN)		7.8
ME5N.F	12	K ₃ (pN)		17.2
HP-3N.F	5	V _{opt} (V)		14.9
HP-4N.F	5	ΔV _{opt} (V)		9.6
HP-5N.F	5	τ _{opt} (ms)		38
CC-5-V	16			
CCG-V-F	10			
CCPC-33	3			
CCPC-34	3			
CCPC-35	2			
PPTUI-3-2	3			
<i>Total</i>	100			

Example 3

Compound	Amount (wt%)	T_{NI} (°C)		92.3
ME2N.F	7	$\Delta\epsilon$		43.1
ME3N.F	6.5	Δn		0.1402
ME4N.F	6.5	K_1 (pN)		8.3
HP-3N.F	5	K_3 (pN)		14.1
HP-4N.F	4.5	V_{opt} (V)		14.5
HP-5N.F	4.5	ΔV_{opt} (V)		4.7
CC-5-V	20	τ_{opt} (ms)		45
CCG-V-F	16			
CCPC-33	3			
CCPC-34	3			
CCPC-35	3			
PZU-V2-N	15			
PPTUI-3-2	6			
<i>Total</i>	100			

Example 4

Compound	Amount (wt%)	T_{NI} (°C)		97.5
ME2N.F	12	$\Delta\epsilon$		39.1
ME3N.F	10	Δn		0.1454
ME4N.F	4	K_1 (pN)		8.4
ME5N.F	4	K_3 (pN)		19.6
HP-3N.F	6	V_{opt} (V)		18.0
HP-4N.F	6	ΔV_{opt} (V)		14.9
HP-5N.F	6	τ_{opt} (ms)		67
CCG-V-F	8			
CCPC-33	5			
CCPC-34	5			
CCPC-35	5			
PDX-3	12			
PDX-4	9			
PDX-5	8			
<i>Total</i>	100			

Example 5

Compound	Amount (wt%)	T_{NI} (°C)	88.9
ME2N.F	6	$\Delta\epsilon$	38.4
ME3N.F	6	Δn	0.1462
ME4N.F	5	K_1 (pN)	7.8
ME5N.F	5	K_3 (pN)	16.7
HP-3N.F	4	V_{opt} (V)	10.4
HP-4N.F	4	ΔV_{opt} (V)	1.1
HP-5N.F	4	τ_{opt} (ms)	32
CC-5-V	10		
CCG-V-F	16		
CCPC-33	4		
CCPC-34	4		
CCPC-35	4		
PZU-V2-N	10		
PPTUI-3-2	8		
PCH-3N.F.F	10		
<i>Total</i>	100		

20

25

30

Example 6

Compound	Amount (wt%)	T_{NI} (°C)	88.7
ME2N.F	10	$\Delta\epsilon$	44.2
ME3N.F	10	Δn	0.1709
ME4N.F	10	K_1 (pN)	9.4
ME5N.F	10	K_3 (pN)	18.2
PZU-V2-N	10	V_{opt} (V)	11.6
CPTP-301	5	ΔV_{opt} (V)	9.3
CPTP-302	5	τ_{opt} (ms)	36
CPTP-303	5		
D-301	5		
D-302	5		
D-401	5		
D-402	5		
CBC-33F	5		
CBC-53F	5		
CBC-55F	5		
<i>Total</i>	100		

Example 7

Compound	Amount (wt%)	T_{NI} (°C)	91.6
ME2N.F	10	$\Delta\epsilon$	43.3
ME3N.F	10	Δn	0.155
ME4N.F	10	K_1 (pN)	9.9
ME5N.F	10	K_3 (pN)	16.5
PZU-V2-N	10	V_{opt} (V)	11.0
CPTP-301	5	ΔV_{opt} (V)	5.1
CPTP-302	5	τ_{opt} (ms)	20
CPTP-303	5	γ_1 (mPa.s)	319
CC-5-V	20		
CCPC-33	5		
CCPC-34	5		
CCPC-35	5		
<i>Total</i>	100		

Example 8

Compound	Amount (wt%)	T_{NI} (°C)	91.3
ME2N.F	10	$\Delta\epsilon$	46.7
ME3N.F	10	Δn	0.2077
ME4N.F	10	K_1 (pN)	11.1
ME5N.F	10	K_3 (pN)	18.5
PZU-V2-N	10	V_{opt} (V)	16.1
CPTP-301	5	ΔV_{opt} (V)	8.5
CPTP-302	5	τ_{opt} (ms)	8
CPTP-303	5	γ_1 (mPa.s)	452
PTP-102	5		
PTP-201	5		
PTP-301	5		
PTP-302	5		
CCPC-33	5		
CCPC-34	5		
CCPC-35	5		
<i>Total</i>	100		

20

25

30

Example 9

Compound	Amount (wt%)	T _{Ni} (°C)	96.2
ME2N.F	12	Δε	47.0
ME3N.F	12	Δn	0.1508
ME4N.F	12	K ₁ (pN)	7.9
ME5N.F	12	K ₃ (pN)	21.8
HP-3N.F	5	V _{opt} (V)	11.6
HP-4N.F	5	ΔV _{opt} (V)	2.2
HP-5N.F	5	τ _{opt} (ms)	47
CCG-V-F	15		
CCPC-33	2		
CCPC-34	2		
CCPC-35	2		
CCP-V-1	8		
CCP-V2-1	8		
<i>Total</i>	100		

Example 10

Compound	Amount (wt%)	T _{Ni} (°C)	98.1
ME2N.F	10	Δε	46.3
ME3N.F	10	Δn	0.1439
ME4N.F	10	K ₁ (pN)	8.5
ME5N.F	10	K ₃ (pN)	18.4
PZU-V2-N	10	V _{opt} (V)	11.8
CCG-V-F	10	ΔV _{opt} (V)	6.5
CCP-V-1	5	τ _{opt} (ms)	49
CCP-V2-1	5		
CVCP-V-1	5		
CVCP-V-O1	5		
CVCP-1V-O1	5		
CCPC-33	5		
CCPC-34	5		
CCPC-35	5		
<i>Total</i>	100		

Example 11

Compound	Amount (wt%)	T _{NI} (°C)	99.2
ME2N.F	10	Δε	43.3
ME3N.F	10	Δn	0.1453
ME4N.F	10	K ₁ (pN)	9.8
ME5N.F	10	K ₃ (pN)	12.7
PZU-V2-N	10	V _{opt} (V)	14.9
HP-33	10	τ _{opt} (ms)	54
HP-53	10		
HD-34	10		
HD-35	10		
CP-33	5		
CP-35	5		
<i>Total</i>	100		

Comparative Example

MLC-6204 (Merck KGaA, Darmstadt) was tested under similar conditions as the Examples according to the invention:

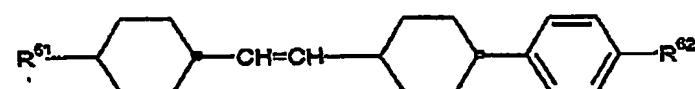
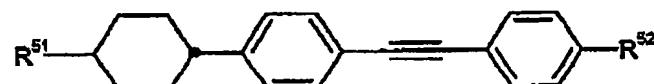
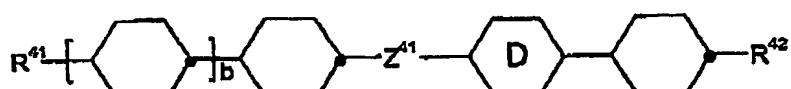
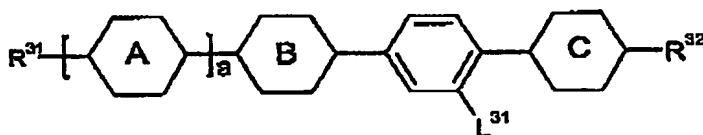
T _{NI} (°C)	62.4
Δε	35.2
Δn	0.1484
K ₁ (pN)	7.5
K ₃ (pN)	14.8
V _{opt} (V)	11.8
ΔV _{opt} (V)	7.3
τ _{opt} (ms)	41
γ ₁ (mPa.s)	358

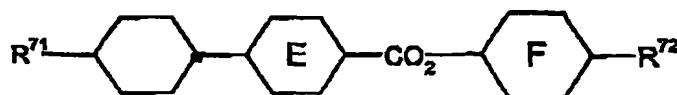
Claims

1. Use of a liquid crystal composition in a bistable liquid crystal device
said composition comprising

5 at least 30 weight% (based on the total weight of the composition) of
a component (α) containing one or more compounds having a
dielectric anisotropy $\Delta\epsilon$ of at least 25,
whereby at least 25 weight% (based on the total weight of the
10 composition) of said compounds have a dielectric anisotropy $\Delta\epsilon$ of at
least 40; and

15 at least 5 weight% (based on the total weight of the composition) of a
component (β);
whereby said component (β) comprises at least one compound of
formula III and/or at least one compound of formula IV and/or at least
one compound of formula V and/or at least one compound of formula
VI and/or at least one compound of formula VII





VII

5

in which

a and b are independently of each other 0 or 1;

10

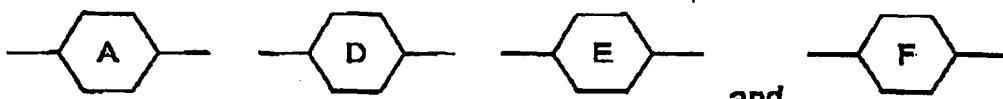
R^{31} , R^{32} , R^{41} , R^{42} , R^{51} , R^{52} , R^{61} , R^{62} , R^{71} and R^{72} are independently of each other C₁-C₁₅ alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH₂ groups may be replaced independently of each other by -O-, -S-, -CH=CH-, -C≡C-, -CO-O-, -OC-O- such that there are no hetero atoms adjacent to each other;

15

 L^{31} is H or F;

20

Z^{41} is -CO-O-, -CH₂O-, -CF₂O-, -CH₂CH₂-, -CF₂CF₂-, -CH₂CF₂-, -CF₂CH₂-, -CH=CH- or -C≡C-;



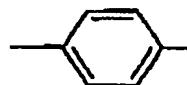
and



or

25

are independently of each other



;

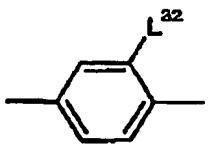
30



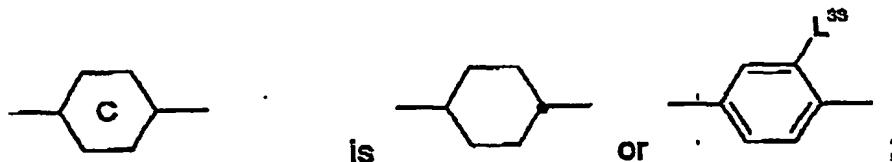
is



or



;

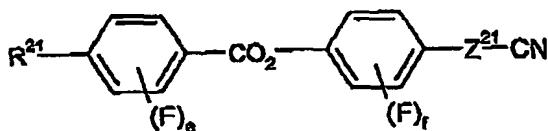
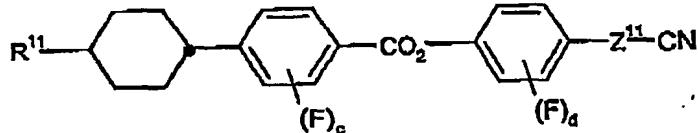


in which

L^{32} and L^{33} are independently of each other H or F.

10 2. Use of a liquid crystal composition according to claim 1 whereby said bistable liquid crystal device is a zenithal bistable nematic liquid crystal device.

15 3. Use of a liquid crystal composition according to any one of claims 1 or 2 whereby said component (a) comprises at least one compound of formula I and/or at least one compound of formula II



in which

c, d, e and f are independently of each other 0, 1, 2, 3 or 4;

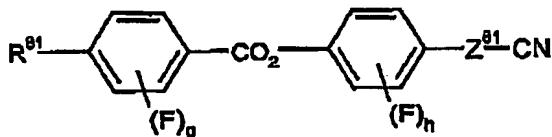
R^{11} is C_1-C_{16} alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced independently of each other by $-O-$, $-S-$, $-CH=CH-$, $-C\equiv C-$, $-CO-O-$, $-OC-O-$ such that there are no hetero atoms adjacent to each other;

30

5 R^{21} is C_2-C_{15} alkenyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced independently of each other by $-O-$, $-S-$, $-CH=CH-$, $-C\equiv C-$, $-CO-O-$, $-OC-O-$ such that there are no hetero atoms adjacent to each other;

10 Z^{11} and Z^{21} are independently of each other a single bond or $-C\equiv C-$.

15 4. Use of a liquid crystal composition according to any one of claims 1 to 3 whereby said component (a) comprises at least one compound of formula VIII



VIII

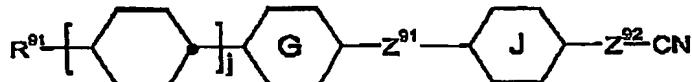
20 in which

25 g and h are independently of each other 0, 1, 2, 3 or 4;

30 R^{81} is C_1-C_{15} alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced independently of each other by $-O-$, $-S-$, $-C\equiv C-$, $-CO-O-$, $-OC-O-$ such that there are no hetero atoms adjacent to each other;

35 Z^{81} is a single bond or $-C\equiv C-$.

40 5. Use of a liquid crystal composition according to any one of claims 1 to 4 whereby said component (a) comprises at least one compound of formula IX



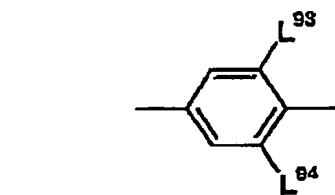
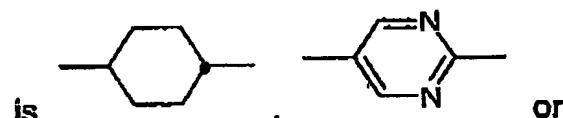
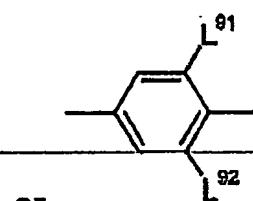
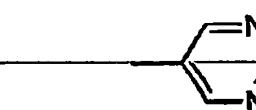
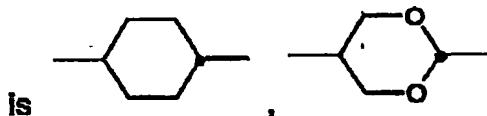
IX

45 in which

50 j is 0 or 1;

5. R^{91} is C_1-C_{15} alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced by $-O-$, $-S-$, $-CH=CH-$, $-C=C-$, $-CO-O-$, $-OC-O-$ such that there are no hetero atoms adjacent to each other;

10 Z^{91} and Z^{92} are independently of each other a single bond or $-C\equiv C-$;



;

in which

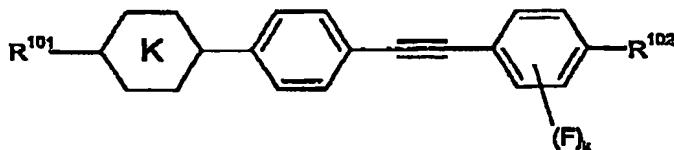
15 L^{91} , L^{92} , L^{93} and L^{94} are independently of each other H or F.

20 6. Use of a liquid crystal composition according to any one of claims 1 to 5 whereby said liquid crystal composition further comprises

- 25 • at least 3 weight% (based on the total weight of the composition) of a component (γ) containing one or more compounds having an optical anisotropy Δn of at least 0,20.

30

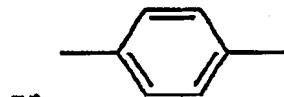
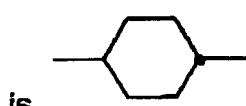
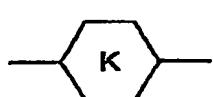
7. Use of a liquid crystal composition according to claim 6 whereby said component (y) comprises at least one compound of formula X



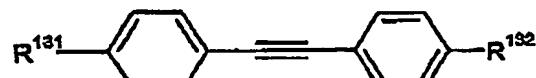
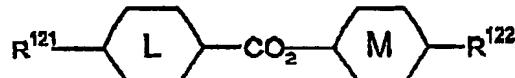
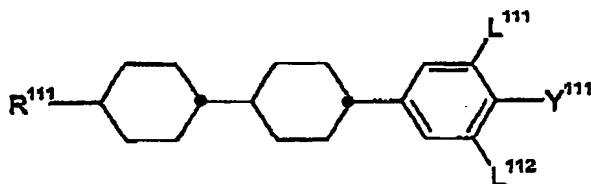
in which

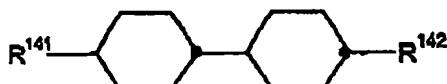
k is 0, 1, 2, 3 or 4;

10 R¹⁰¹ and R¹⁰² are independently of each other C₁-C₁₅ alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH₂ groups may be replaced by -O-, -S-, -CH=CH-, -C≡C-, -CO-O-, -OC-O- such that there are no hetero atoms adjacent to each other; and



8. Use of a liquid crystal composition according to any one of claims 1 to 7 whereby said liquid crystal composition further comprises at least one compound of formula XI and/or at least one compound of formula XII and/or at least one compound of formula XIII at least one compound of formula XIV





XIV

5

in which
 R^{111} and R^{142} are independently of each other C_2 - C_{15} alkenyl
 which is unsubstituted or mono- or poly-substituted with CN or
 halogen and in which one or more of the CH_2 groups may be
 replaced independently of each other by -O-, -S-, - $CH=CH$ -,
 - $C\equiv C$ -, -CO-O-, -OC-O- such that there are no hetero atoms
 adjacent to each other;

10

R^{121} , R^{131} , R^{132} and R^{141} are independently of each other C_1 - C_{15}
 alkyl which is unsubstituted or mono- or poly-substituted with
 CN or halogen and in which one or more of the CH_2 groups

15

may be replaced independently of each other by -O-, -S-,
 - $CH=CH$ -, - $C\equiv C$ -, -CO-O-, -OC-O- such that there are no
 hetero atoms adjacent to each other;

R^{122} is C_1 - C_{15} alkyl which is unsubstituted or mono- or poly-
 substituted with halogen and in which one or more of the CH_2
 groups may be replaced independently of each other by -O-,
 -S-, - $CH=CH$ -, - $C\equiv C$ -, -CO-O-, -OC-O- such that there are no
 hetero atoms adjacent to each other;

20

Y^{111} is F, Cl, C_1 - C_{15} alkanyl which is mono- or poly-substituted with
 halogen, or C_1 - C_{15} alkoxy, which is mono- or poly-substituted
 with halogen;

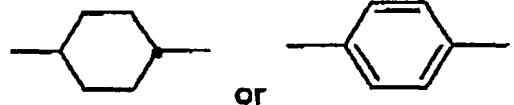
25

L^{111} and L^{112} are independently of each other H or F; and



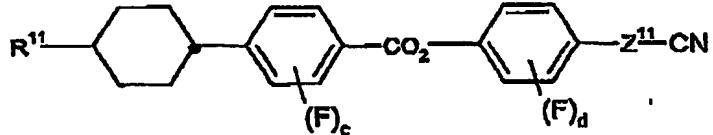
and

are independently of each other



30

9. Use of a liquid crystal composition according to any one of claims 1 to 8 whereby said liquid crystal composition comprises at least 50 weight% (based on the total weight of the composition) of said component (α).
10. Use of a liquid crystal composition according to any one of claims 1 to 9 whereby said liquid crystal composition comprises at least 50 weight% (based on the total weight of the composition) of said component (α) whereby at least 30 weight% (based on the total weight of the composition) of said compounds have a dielectric anisotropy $\Delta\epsilon$ of at least 40.
11. Use of a liquid crystal composition according to any one of claims 1 to 10 whereby said liquid crystal composition comprises at least one compound of formula II of said component (α) and at least 8 weight% (based on the total weight of the composition) of said component (β).
12. Use of a liquid crystal composition according to any one of claims 6 to 11 whereby said liquid crystal composition comprises at least 5 weight% (based on the total weight of the composition) of said component (γ).
13. Liquid crystal medium comprising
 - at least one compound of formula I

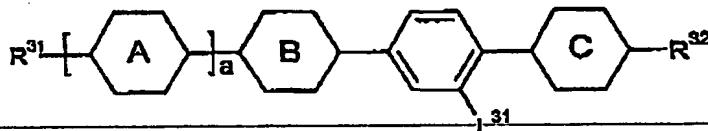


c and d are independently of each other 0, 1, 2, 3 or 4;

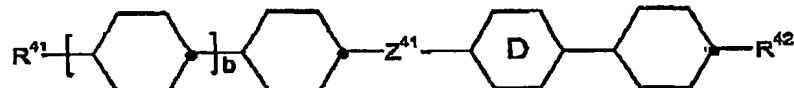
5 R^{11} is C_1-C_{15} alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced independently of each other by $-O-$, $-S-$, $-CH=CH-$, $-C\equiv C-$, $-CO-O-$, $-OC-O-$ such that there are no hetero atoms adjacent to each other; and

10 Z^{11} is a single bond or $-C\equiv C-$.

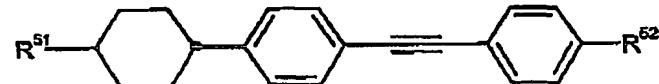
- at least one compound of formula III and/or at least one compound of formula IV and/or at least one compound of formula V and/or at least one compound of formula VI and/or at least one compound of formula VII



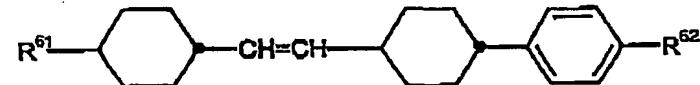
III



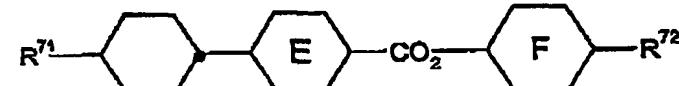
IV



V



VI



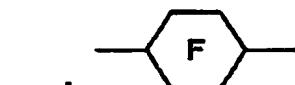
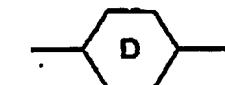
VII

in which

40 a and b are independently of each other 0 or 1;
 $R^{31}, R^{32}, R^{41}, R^{42}, R^{51}, R^{52}, R^{61}, R^{62}, R^{71}$ and R^{72} are independently of each other C_1-C_{15} alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced independently of each other by $-O-$, $-S-$, $-CH=CH-$, $-C\equiv C-$, $-CO-O-$, $-OC-O-$ such that there are no hetero atoms adjacent to each other; and

5 L^{31} is H or F;

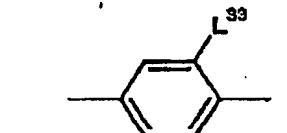
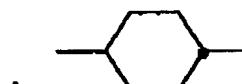
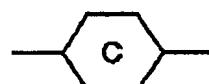
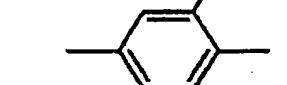
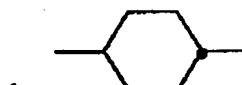
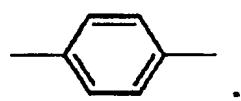
10 Z^{41} is $-CO-O-$, $-CH_2O-$, $-CF_2O-$, $-CH_2CH_2-$, $-CF_2CF_2-$, $-CH_2CF_2-$,
 $-CF_2CH_2-$, $-CH=CH-$ or $-C\equiv C-$;



and



or



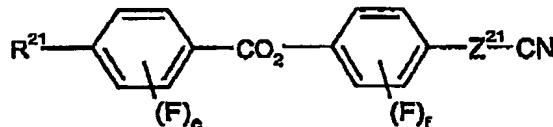
in which

14. L^{32} and L^{33} are independently of each other H or F.

20

14. Liquid crystal medium comprising

- at least one compound of formula II



II

in which

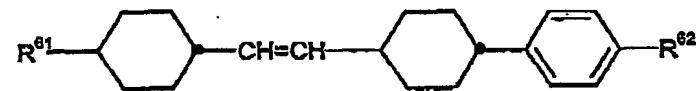
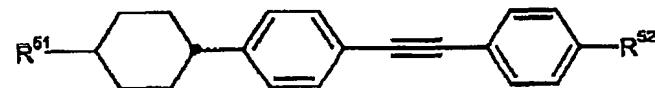
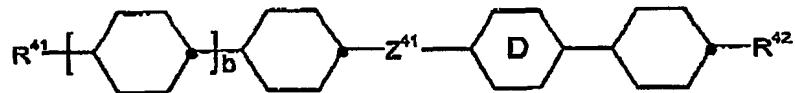
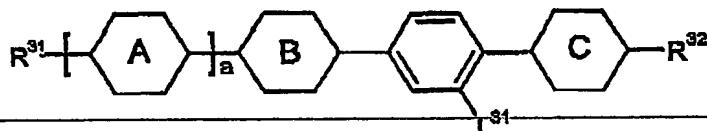
e and f are independently of each other 0, 1, 2, 3 or 4;

30

5 R^{21} is C_2-C_{15} alkenyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced independently of each other by $-O-$, $-S-$, $-CH=CH-$, $-C\equiv C-$, $-CO-O-$, $-OC-O-$ such that there are no hetero atoms adjacent to each other;

10 Z^{21} is a single bond or $-C\equiv C-$.

- at least one compound of formula III and/or at least one compound of formula IV and/or at least one compound of formula V and/or at least one compound of formula VI and/or at least one compound of formula VII



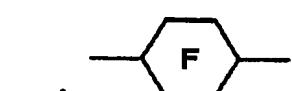
in which

a and b are independently of each other 0 or 1;

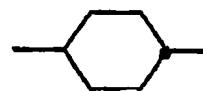
R^{31} , R^{32} , R^{41} , R^{42} , R^{51} , R^{52} , R^{61} , R^{62} , R^{71} and R^{72} are independently of each other C_1-C_{15} alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced independently of each other by $-O-$, $-S-$, $-CH=CH-$, $-C\equiv C-$, $-CO-O-$, $-OC-O-$ such that there are no hetero atoms adjacent to each other; and

5 L^{31} is H or F;

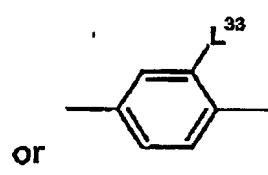
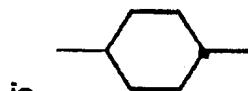
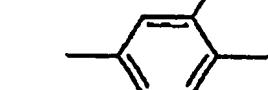
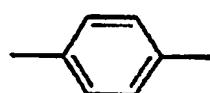
10 Z^{41} is $-CO-O-$, $-CH_2O-$, $-CF_2O-$, $-CH_2CH_2-$, $-CF_2CF_2-$, $-CH_2CF_2-$,
 $-CF_2CH_2-$, $-CH=CH-$ or $-C\equiv C-$;



and



or



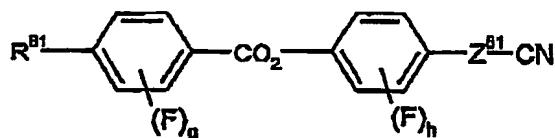
in which

20 L^{32} and L^{33}

25 are independently of each other H or F.

15. Liquid crystal medium according to any one of claims 13 or 14
 characterized in that said medium further comprises at least one
 compound of formula VIII

25



VIII

30 g and h are independently of each other 0, 1, 2, 3 or 4;

5 R^{81} is C_1 - C_{15} alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced independently of each other by -O-, -S-, -C≡C-, -CO-O-, -OC-O- such that there are no hetero atoms adjacent to each other;

10 Z^{81} is a single bond or -C≡C-.

15 16. Bistable liquid crystal device comprising

- two outer substrates which, together with a frame, form a cell;
- a liquid crystal composition present in said cell;
- electrode structures with alignment layers on the inside of said outer substrates whereby at least one alignment layer comprises an alignment grating that permits the compounds of said liquid crystal composition to adopt at least two different stable states whereby the assembly of said electrode structures with said alignment layers being such that a switching between the said at least two different stable states is achieved by applying suitable electric signals to said electrode structures;
- whereby said liquid crystal composition comprises
 - at least 30 weight% (based on the total weight of the composition) of a component (a) containing one or more compounds having a dielectric anisotropy $\Delta\epsilon$ of at least 25, whereby at least 25 weight% (based on the total weight of the composition) of said compounds have a dielectric anisotropy $\Delta\epsilon$ of at least 40; and

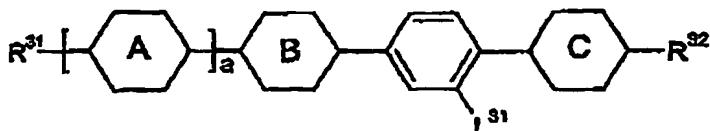
20

25

30

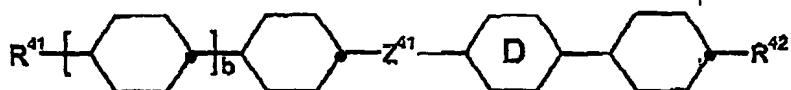
5 • at least 5 weight% (based on the total weight of the composition) of a component (β);
 whereby said component (β) comprises at least one compound of formula III and/or at least one compound of formula IV and/or at least one compound of formula V and/or at least one compound of formula VI and/or at least one compound of formula VII

10



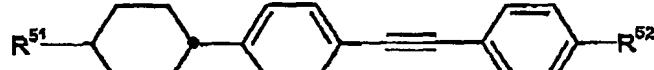
III

15

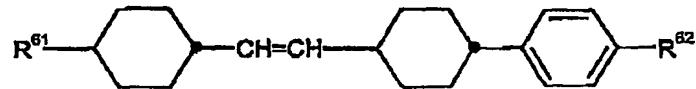


IV

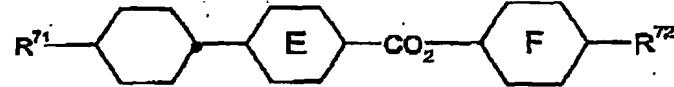
20



V



VI



VII

in which

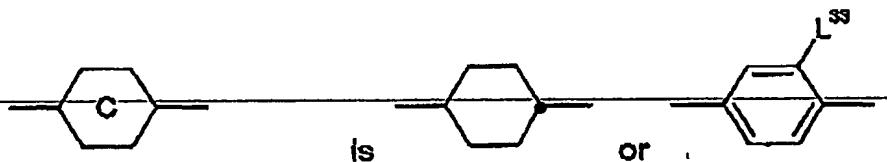
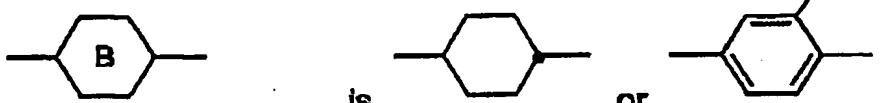
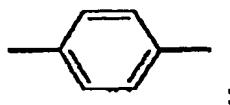
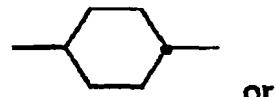
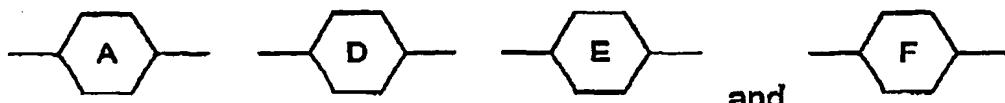
a and b are independently of each other 0 or 1;

25 R^{31} , R^{32} , R^{41} , R^{42} , R^{51} , R^{52} , R^{61} , R^{62} , R^{71} and R^{72} are independently of each other C_1-C_{15} alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced independently of each other by $-O-$, $-S-$, $-CH=CH-$, $-C=C-$, $-CO-O-$, $-OC-O-$ such that there are no hetero atoms adjacent to each other; and

30

L^{31} is H or F;

Z^{41} is $-CO-O-$, $-CH_2O-$, $-CF_2O-$, $-CH_2CH_2-$, $-CF_2CF_2-$, $-CH_2CF_2-$, $-CF_2CH_2-$, $-CH=CH-$ or $-C=C-$;



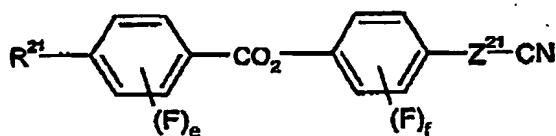
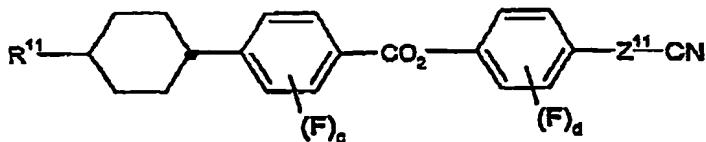
15 in which
L³² and L³³ are independently of each other H or F.

17. Bistable liquid crystal device according to claim 16 whereby

20 ■ said device is a zenithal bistable nematic liquid crystal device;
and

25 ■ said electrode structures with alignment layers on the inside of
said outer substrates have at least one alignment layer that
comprises an alignment grating that permits the compounds of
said liquid crystal composition to adopt at least two different stable
states with different pretilt angles in the same azimuthal plane.

18. Bistable liquid crystal device according to any one of claims 16 or 17
30 whereby said component (α) comprises at least one compound of
formula I and/or at least one compound of formula II



In which

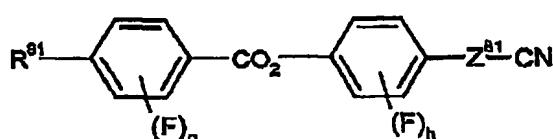
c, d, e and f are independently of each other 0, 1, 2, 3 or 4;

15 R^{11} is $\text{C}_1\text{-C}_{15}$ alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced independently of each other by $-\text{O}-$, $-\text{S}-$, $-\text{CH}=\text{CH}-$, $-\text{C}\equiv\text{C}-$, $-\text{CO-O}-$, $-\text{OC-O-}$ such that there are no hetero atoms adjacent to each other;

20 R^{21} is $\text{C}_2\text{-C}_{15}$ alkenyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced independently of each other by $-\text{O}-$, $-\text{S}-$, $-\text{CH}=\text{CH}-$, $-\text{C}\equiv\text{C}-$, $-\text{CO-O}-$, $-\text{OC-O-}$ such that there are no hetero atoms adjacent to each other;

25 Z^{11} and Z^{21} are independently of each other a single bond or $-\text{C}\equiv\text{C}-$.

19. Bistable liquid crystal device according to any one of claims 16 to 18 whereby said component (a) comprises at least one compound of formula VIII



VIII

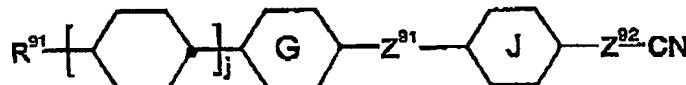
in which

30 g and h are independently of each other 0, 1, 2, 3 or 4;

5 R^{81} is C_1-C_{15} alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced independently of each other by $-O-$, $-S-$, $-C\equiv C-$, $-CO-O-$, $-OC-O-$ such that there are no hetero atoms adjacent to each other;

10 Z^{81} a single bond or $-C\equiv C-$.

20. Bistable liquid crystal device according to any one of claims 16 to 19 whereby said component (a) comprises at least one compound of formula IX



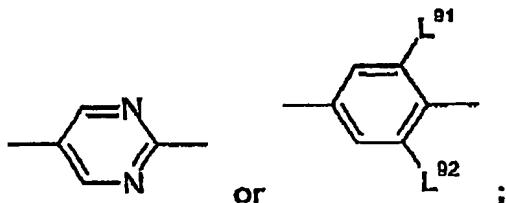
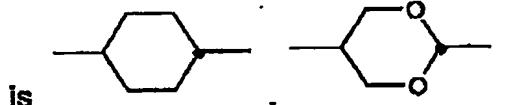
IX

15 in which

j is 0 or 1;

20 R^{81} is C_1-C_{15} alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH_2 groups may be replaced by $-O-$, $-S-$, $-CH=CH-$, $-C\equiv C-$, $-CO-O-$, $-OC-O-$ such that there are no hetero atoms adjacent to each other;

25 Z^{81} and Z^{82} are independently of each other a single bond or $-C\equiv C-$;

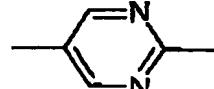
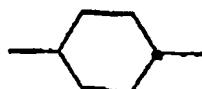


30

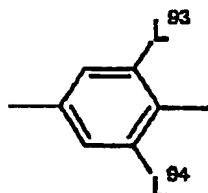
- 92 -



is



or



in which

 L^{91}, L^{92}, L^{93} and L^{94} are independently of each other H or F.

5

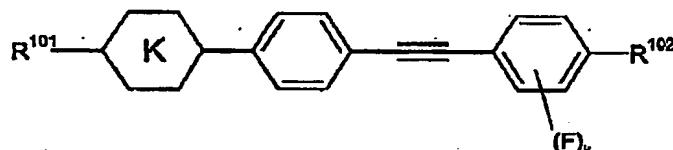
21. Bistable liquid crystal device according to any one of claims 16 to 20 whereby said liquid crystal composition further comprises

- at least 3 weight% (based on the total weight of the composition) of a component (y) containing one or more compounds having an optical anisotropy Δn of at least 0,20.

15

22. Bistable liquid crystal device according to claim 21 whereby said component (y) comprises at least one compound of formula X

20



X

in which

k is 0, 1, 2, 3 or 4;

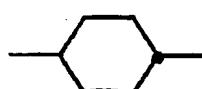
25

R^{101} and R^{102} are independently of each other C₁-C₁₅ alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH₂ groups may be replaced by -O-, -S-, -CH=CH-, -C≡C-, -CO-O-, -OC-O- such that there are no hetero atoms adjacent to each other; and

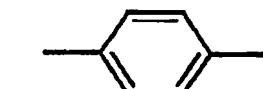
30



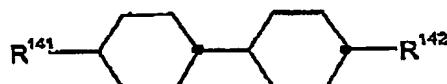
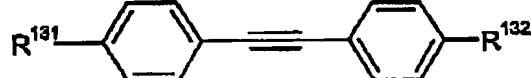
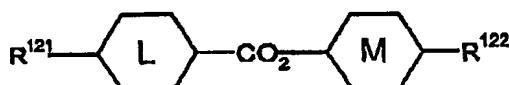
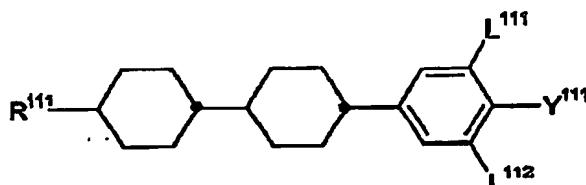
is



or



23. Bistable liquid crystal device according to any one of claims 16 to 22 whereby said liquid crystal composition further comprises at least one compound of formula XI and/or at least one compound of formula XII and/or at least one compound of formula XIII and/or at least one compound of formula XIV



in which

20

R¹¹¹ and R¹⁴² are independently of each other C₂-C₁₅ alkenyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH₂ groups may be replaced independently of each other by -O-, -S-, -CH=CH-, -C≡C-, -CO-O-, -OC-O- such that there are no hetero atoms adjacent to each other;

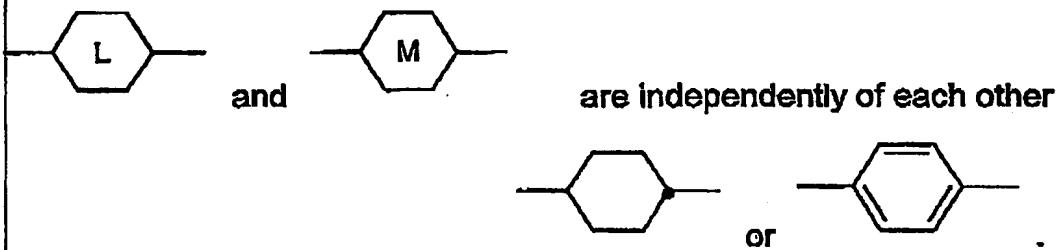
25

R¹²¹, R¹³¹, R¹³² and R¹⁴¹ are independently of each other C₁-C₁₅ alkyl which is unsubstituted or mono- or poly-substituted with CN or halogen and in which one or more of the CH₂ groups may be replaced independently of each other by -O-, -S-, -CH=CH-, -C≡C-, -CO-O-, -OC-O- such that there are no hetero atoms adjacent to each other;

5 R^{122} is C_1-C_{15} alkyl which is unsubstituted or mono- or poly-substituted with halogen and in which one or more of the CH_2 groups may be replaced independently of each other by $-O-$, $-S-$, $-CH=CH-$, $-C\equiv C-$, $-CO-O-$, $-OC-O-$ such that there are no hetero atoms adjacent to each other;

10 Y^{111} is F, Cl, C_1-C_{15} alkanyl which is mono- or poly-substituted with halogen, or C_1-C_{15} alkoxy, which is mono- or poly-substituted with halogen;

15 L^{111} and L^{112} are independently of each other H or F; and



30 24. Bistable liquid crystal device according to any one of claims 16 to 23 whereby said liquid crystal composition comprises at least 50 weight% (based on the total weight of the composition) of said component (a).

35 25. Bistable liquid crystal device according to any one of claims 16 to 24 whereby said liquid crystal composition comprises at least 50 weight% (based on the total weight of the composition) of said component (a) whereby at least 30 weight% (based on the total weight of the composition) of said compounds have a dielectric anisotropy $\Delta\epsilon$ of at least 40.

40 26. Bistable liquid crystal device according to any one of claims 16 to 25 whereby said liquid crystal composition comprises at least one compound of formula II of said component (a) and at least 8 weight% (based on the total weight of the composition) of said component (b).

27. Bistable liquid crystal device according to any one of claims 21 to 26
whereby said liquid crystal composition comprises at least 5 weight%
(based on the total weight of the composition) of said component (y).

5

10

15

20

25

30

Abstract

The invention is directed to the use of a liquid crystal composition in a bistable liquid crystal device and especially in a zenithal bistable nematic liquid crystal device, a nematic liquid crystal medium, and a bistable liquid crystal device comprising the liquid crystal composition whereby said liquid crystal composition comprises at least 30 weight% (based on the total weight of the composition) of a component (a) containing one or more compounds having a dielectric anisotropy $\Delta\epsilon$ of at least 25, whereby at least 25 weight% (based on the total weight of the composition) of said compounds have a dielectric anisotropy $\Delta\epsilon$ of at least 40; and at least 5 weight% of a component (b).

15

20

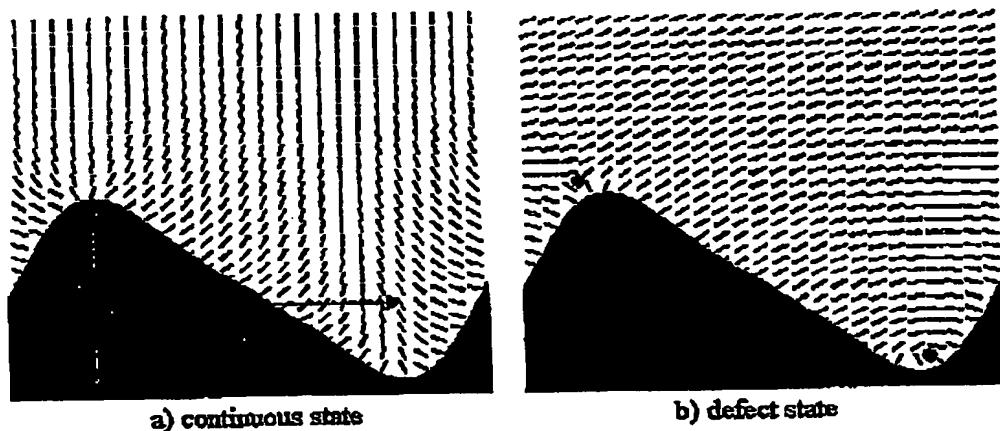
25

30

Figures

5

10



15

20

30

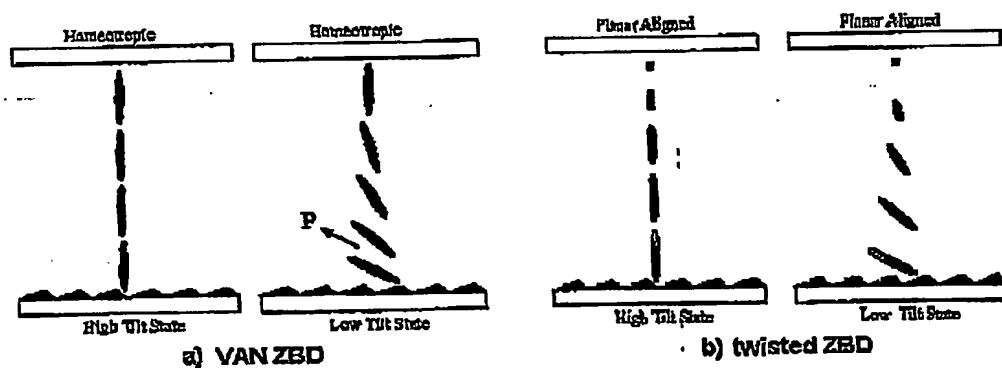


Figure 2. The a) VAN and b) TN geometries for ZBD showing the director distribution of the high and low tilt states.

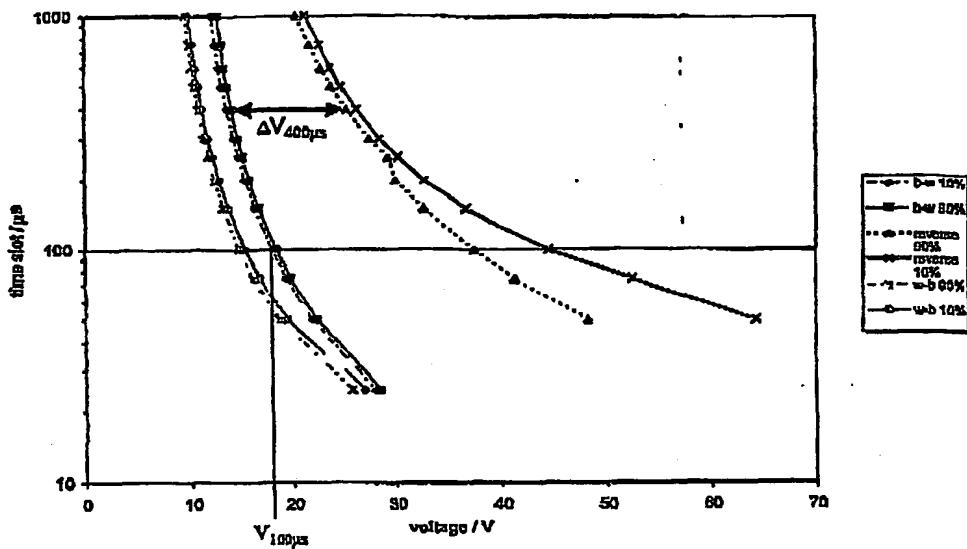


Figure 3. The τ -V curve for MLC-6204-000 at 25°C (pulse duration or time slot vs. voltage). The switching voltage ($V_{100\mu s}$) and operating window ($\Delta V_{400\mu s}$) used for comparisons are indicated.

5

10

15

20

25

30

PCT Application

EP0312953



**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- BLACK BORDERS**
- IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- FADED TEXT OR DRAWING**
- BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- SKEWED/SLANTED IMAGES**
- COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- GRAY SCALE DOCUMENTS**
- LINES OR MARKS ON ORIGINAL DOCUMENT**
- REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.